NORTHWEST
FOREST PLAN
THE FIRST TEN YEARS (1994–2003)

A Synthesis of Monitoring and Research Results

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Technical Editors

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Northwest Forest Plan—The First 10 Years (1994-2003): Synthesis of Monitoring and Research Results

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Abstract

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It has been 10 years since the Northwest Forest Plan (the Plan) came into being at the direction of President Clinton. This report synthesizes the status and trends of five major elements of the Plan: older forests, species, aquatic systems, socioeconomics, and adaptive management and monitoring. It synthesizes new science that has resulted from a decade of research. The report also contains key management implications for federal agencies. This report is a step in the adaptive management approach adopted by the Plan, and there is the expectation that its findings will lead to changes in the next decade of Plan implementation.

Although most of the monitoring has been underway for less than a decade and many of the Plan's outcomes are expected to evolve over decades, the monitoring is already producing a wealth of data about the status and trends in abundance, extent, diversity, and ecological functions of older forests, the species that depend on them, and how humans relate to them. Conditions did change over the decade. Watershed conditions improved, increase in acreage of late-successional old growth exceeded expectations, new species now pose threats, and there is greater appreciation of the need to share habitat protection among land ownerships. The Plan anticipated greater timber harvests and more treatments to reduce fuel in fire-prone stands than have actually occurred. Monitoring showed human communities are highly variable, and it is difficult to disentangle overall growth in regional economies from the impacts of reduced timber harvests on federal land.

Keywords: Northwest Forest Plan, northern spotted owl, old growth, forest policy, biodiversity.

Preface

This report is one of a set of reports produced on this 10-year anniversary of the Northwest Forest Plan (the Plan). The collection of reports attempts to answer questions about the effectiveness of the Plan based on new monitoring and research results. The set includes a series of status and trends reports, a synthesis of all regional monitoring and research results, a report on interagency information management, and a summary report.

The status and trends reports focus on establishing baselines of information from 1994, when the Plan was approved, and reporting change over the 10-year period. The status and trends series includes reports on late-successional and old-growth forests, northern spotted owl population and habitat, marbled murrelet population and habitat, watershed condition, government-to-government tribal relationships, socioeconomic conditions, and monitoring of project implementation under Plan standards and guidelines.

The synthesis report addresses questions about the effectiveness of the Plan by using the status and trends results and new research. It focuses on the validity of the Plan assumptions, differences between expectations and what actually happened, the certainty of these findings, and, finally, considerations for the future. The synthesis report is organized in three parts: Part I—introduction, context, synthesis, and summary; Part II—socioeconomic implications, older forests, species conservation, the aquatic conservation strategy, and adaptive management and monitoring; and Part III—key management implications.

The report on interagency information management identifies issues and recommends solutions for resolving data and mapping problems encountered during the preparation of the set of monitoring reports. Information issues inevitably surface during analyses that require data from multiple agencies covering large geographic areas. The goal of this set of reports is to improve the integration and acquisition of interagency data for the next comprehensive report.

Parts I and II of the synthesis report were written by a team assembled to review the various information and status and trends reports. Five of the team members (Haynes, Marcot, Raphael, Reeves, Spies) participated on various Forest Ecosystem Management Assessment Team (FEMAT) science teams; two worked on implementing the forest plan on the management side (Martin, N. Molina); three (Bormann, Kiester, Martin) worked on implementing adaptive management; and seven (Busch, Marcot, Martin, R. Molina, Raphael, Reeves, Spies) worked on implementing various monitoring modules. Eleven of the team members are from USDA Forest Service Research; two are from USDA Forest Service, Pacific Northwest Region; one is from USDI Geological Survey; and one is from USDI Bureau of Land Management.

Part III was written by a Team from the management community. Four (N. Molina, Johnson, Cissel, Willamson) are from USDI Bureau of Land Management, and four are from the USDA Forest Service (Hussey, Emch, Fenwood, Smith), and one (Mulder) is from the U.S. Fish and Wildlife Service.

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Summary

In the early 1990s, public controversy over timber harvest in old-growth forest of the Pacific Northwest, decline of the threatened northern spotted owl (see appendix for scientific names) and the marbled murrelet, habitat protection for Pacific salmon populations, and perceived threats to the social well-being of forest-based communities challenged federal land managers. The ensuing controversy ultimately led to a Presidential conference in 1993 where President Clinton issued a mandate for federal land management and regulatory agencies to work together to develop a plan for resolving the conflict between timber and other resource values. President Clinton listed the following five principles that he felt should guide the process (FEMAT 1993):

> First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can preserve the health of forest lands, [timber] sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs.
>
> Second, as we craft a plan, we need to protect the long-term health of our forests, our wildlife, and our waterways. They are a…gift from God; and we hold them in trust for future generations.
>
> Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecologically credible, and legally responsible.
>
> Fourth, the plan should produce a predictable and sustainable level of timber sales and nontimber resources that will not degrade or destroy the environment.
>
> Fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you. We may make mistakes but we will try to end the gridlock within the federal government, and we will insist on collaboration not confrontation.

The result was the Northwest Forest Plan that amended the planning documents for 19 national forests and 7 Bureau of Land Management districts (USDA and USDI 1994) and that has guided federal forest management in the Northwest for the past decade. This report is an important step in the adaptive management approach adopted as part of the Plan. It synthesizes the status and trends of five major elements of the Plan: older forests, species, aquatic systems, socioeconomics, and adaptive management. It also synthesizes new science that has resulted from 10 years of research related to the Plan. We finish by addressing four interconnected questions: (1) Has the Plan resulted in changes that are consistent with objectives identified by President Clinton? (2) Are major assumptions behind the Plan still valid? (3) Have we advanced learning through monitoring and adaptive management? and (4) Does the Plan provide robust direction for the future?

Trends and Findings

Older Forests

The original design of the Plan attempted to develop alternatives that would create or maintain “a connected or interactive old-growth forest ecosystem on the federal land within the region under consideration.” There was concern that the amount of older forest had steeply declined during the 20th century, placing associated species and desired ecosystem functions at risk of extinction. The premise of the proposed solutions was to return the amount of older forest on federal lands to levels that were more similar to what they had been prior to widespread logging. Possible outcomes of the Plan for older forests were described in terms of their likelihood of returning levels of older forest to the historical range of variation that may have occurred prior to Euro-American settlement.

After 10 years of monitoring a plan whose outcomes are expected to evolve over 100 years or more, it appears that the status and trends in abundance, diversity, and ecological functions of older forests are generally consistent with expectations of the Plan. The total area of late-successional and old-growth forest (older forests) has increased at a rate that is somewhat higher than expected, and losses from wildfires are in line with what was anticipated. Research since the Plan supports the application of creative silvicultural practices to diversify plantations and accelerate the development of some components of old-growth forest.

The characterization of old growth used in the Plan is generally still valid; however, researchers have become aware that the diversity and complexity of natural forests are greater than portrayed in some of our earlier conceptual models. Old-growth forest is part of a complex continuum of forest development in which younger stages may contain elements of old growth, and old-growth forest may contain elements of younger forest that arise following natural disturbances of many kinds. Given the complexity of forest development, conserving forest biodiversity requires considering elements or structures from all stages of stand development.

Monitoring suggests that rates of fuel treatments and restoration of structure and disturbance regimes in fire-dependent older forest types have been considerably less than is needed to reduce potential for losses of these forests to severe disturbance and successional change. Landscape management strategies that balance fuel reduction and short-term maintenance of northern spotted owl habitat are needed to reduce the potential for fires that destroy both owl habitat and large conifer trees that serve as the building blocks of dry-forest restoration. The Plan designated areas of land (often containing the remaining old-growth forests) as reserves, meant to conserve habitat for certain species. Reexamination of the reserve strategy of the Plan and alternatives indicates that active management within reserves may be needed in both dry and wet forests to restore ecological diversity and reduce potential for loss from severe fire.

The Plan recognized the ecological value of standing dead trees and downed logs in postwildfire ecosystems and placed restrictions on salvage logging within reserves. Science that has emerged since then supports this policy. However, no new scientific information has developed that can be used as the sole basis for setting salvage levels and still be consistent with the goals of the Plan. Some new information suggests that more dead wood be left, but the ultimate management decision involves weighing the ecological, social, and economic risks and tradeoffs.

The Plan focused on federal lands, which make up 41 percent of the forest land in the Pacific Northwest, and made the assumption that federal lands would carry most of the weight in conserving species and old-forest systems. Research conducted since the Plan indicates that assumption is not necessarily valid and that conditions on nonfederal lands could contribute to Plan goals or, in some cases, hinder achievement of those goals.

Monitoring trends and reevaluation of Plan assumptions do not indicate a compelling reason for major changes to reserve boundaries in moist habitats at this time. In dry provinces, however, there is a need to consider if new landscape management strategies would better reduce risks of loss of older forest and owl habitat to catastrophic fire.

Given the relatively short period for monitoring and lack of reliable information about future losses from high-severity wildfires and climate change, significant uncertainties remain about the long-term trends in old forest, especially in the dry provinces.

Aquatic Conservation Strategy

The Aquatic Conservation Strategy has met many of the expectations for it. The strategy was designed to maintain and restore the productivity and resiliency of riparian and aquatic ecosystems. Its focus is habitat rather than species populations because, for anadromous species such as salmon, ocean currents and other factors outside the control of forest management affect their numbers. The monitoring program suggests that the conditions of many watersheds had improved over the past decade. Most watersheds (161 of those 250 monitored) showed small positive changes in watershed condition scores. These results should be viewed cautiously as they were not based on a complete set of parameters, and the program has not completed a full cycle of sampling. Main determinates of an improved watershed condition were an increase in the number of large trees in riparian areas and a decrease in clearcut harvesting in riparian zones. Trends will continue to improve if the strategy continues to be implemented in its current form.

Scientific studies completed after the Plan was implemented continue to support the framework and assumptions of the Aquatic Conservation Strategy, particularly the ecological importance of smaller, headwater streams and the retention of streamside forests protected in buffers. Also, a growing body of science about the dynamics of aquatic and riparian ecosystems could provide a foundation for developing new management approaches and policies. Scientifically based tools for aiding watershed analysis are also available and could be used by the various agencies.

A continuing challenge is the relation among spatial scales considered at the project level, the Aquatic Conservation Strategy, and the Plan. The strategy changed the focus of land management agencies from small spatial scales, such as stands and small watersheds, to larger watersheds and complex landscapes. This latter scale sets the context for adjusting actions at the project scale. The implications of introducing flexibility at the site level have not been fully recognized or appreciated by the land management or regulatory agencies and have created confusion with the public and policymakers.

Conservation of Species

Owls and Murrelets—

The reserve system was created to conserve habitat for the northern spotted owl and marbled murrelet. Ten years is a short time relative to the time needed for habitat recovery from past disturbance, and populations may not show increases in response to habitat restoration until more time has elapsed.

Populations of the northern spotted owl are declining in the northern parts of the subspecies range; reasons are unclear, but lingering effects of past harvest and synergistic interactions of weather, habitat, and displacement by the barred owl are likely causes. Based on 4 years of monitoring, marbled murrelet populations seem stable, but more years of survey are needed to be confident in estimated trends. Populations of wideranging species like the owl and murrelet respond to the cumulative effects of many interacting factors, only some of which are under the direct influence of the Plan. Therefore, observed short-term population trends of these species may or may not be due to land management decisions under the Plan. The system of reserves, however, has clearly been successful in conserving nesting habitat, and restoration of unsuitable habitat within reserves seems likely.

Losses of habitat to fire and logging on federal lands have been lower than expected.

Substantial area of habitat for owls and murrelets occur on nonfederal lands; rate of loss owing to logging on those lands has been greater than on federal lands and those losses will likely continue.

Other facets of biodiversity—

The Plan called for assessing other species associated with older forest as part of a program to monitor biodiversity of late-successional and old-growth forest ecosystems. One aspect of this was embodied in the Survey and Manage program that focused on inventory of rare and little-known species. Other elements of biodiversity have not been monitored.

The assumption that the Plan (particularly the reserve system) provided for old-growth-associated species—remains untested. However, as over 90 percent of federal land is in reserve status, it is highly likely that many of these species are protected. The application of coarse-filter approaches to management, namely the land management allocations and mitigations under the Plan, provides some protection for rare and little-known survey and manage and old-growth-associated species, but there remains uncertainty as to their persistence and viability.

After 10 years of surveys, most Survey and Manage species were found to be rare (42 percent are known from 10 or fewer sites) with many sites outside of reserve land allocations. Maintaining persistence of extremely rare species may require continuing fine-filter conservation approaches, including protection of known sites. The experience with the Survey and Manage species has led to changes in gauging conservation requirements for selected species. It also has led to further research questions on basic distribution, trends, and ecology for many species.

Socioeconomic Conditions

The political compromise leading to the Plan linked timber production on federal lands with jobs and community well-being. Since implementing the Plan, the debate has been generalized to imply that increased environmental protection threatens jobs and, therefore, community stability. These issues framed the socioeconomic monitoring questions.

The first two questions address the effectiveness of a predictable and sustainable supply of goods and recreation opportunities to maintain the stability of local and regional economies. In general, the Plan enabled federal agencies to resume activities. In terms of output levels, timber sale expectations were not met, grazing and mineral activity declined, and recreation opportunities remained relatively constant. Changes took place in all of the communities across the region, and although it is difficult to disentangle changes caused by the Plan from other changes, there are individuals who still express a sense of lost social and economic opportunities from the reductions in federal resource flows.

The third question focused on the effects of mitigation activities where federal agencies working with state agencies and community groups attempted to minimize adverse impacts on jobs by assisting with economic development and diversification opportunities in those rural communities most affected by the cutbacks in federal timber sales. The results of these efforts were mixed; overall growth in regional economies reduced the impacts of reduction in federal timber flow, and the economic adjustment initiative provided less help to displaced workers than expected.

The monitoring results for the fourth question, based on the President's principle of protecting broad environmental values for future generations, are mixed. Old-growth-related species and many of the uses and values that urban people associate with forests were protected. The uses and values that rural people associate with forests were not protected to the same extent. Old-growth trees or stands were not protected outside of late-successional or riparian reserves, and regions outside the Pacific Northwest bore the brunt of increased harvests to offset harvest reductions in the Northwest.

The Plan did engender considerable new collaboration between and among the federal agencies. It established overarching institutions like the Regional Ecosystem Office to coordinate activities among federal agencies. The Plan also relied on public engagement in new forums, such as the regional and provincial advisory committees, to deliver benefits to communities.

In the last decade, societal concerns about forest management have broadened. Concerns used to focus on species conservation; now the emphasis is on achieving sustainable forests across all forest lands. Social acceptance of forest management has also shifted, suggesting the importance of building and maintaining trust with citizens. Concern about community dependency has shifted to concern about community adaptability. The Plan has also demonstrated the importance of strengthening governance when implementing broad-scale forest management that crosses multiple land ownerships and management agencies.

Adaptive Management

Adaptive management was considered the cornerstone of the Plan strategy. Because of the known uncertainties—and the simple fact that Plan approaches had never been tried before—adaptive management was recognized as the mechanism to alter Plan direction as more was learned. The Plan directed managers to experiment, monitor, and interpret as activities were applied both inside and outside adaptive management areas—and to do this as a basis for changing the Plan in the future.

The implementation of adaptive management, however, has proceeded in fits and starts. This report represents one step in a successful approach to adaptive management. We have summarized the results of 10 years of monitoring, and there is the expectation that the management implications of this will lead to changes in Plan implementation. There have been difficulties, however. The first difficulty was the lack of a single definition of adaptive management. A passive form of adaptive management was most commonly used in the Plan; a single approach was chosen (for example, on the reserves, the preserve and protect tenets of conventional conservation biology were used) and then regional monitoring became the primary feedback and learning mechanism. Management experiments were limited to small, tightly controlled areas and seldom included participation by the regulatory agencies.

Expectations for a more active form, advocated by many researchers, were not achieved except for a few landscape areas. In retrospect, the regulatory agencies could have been more thoughtfully engaged in the learning efforts. Successful implementation of adaptive management remains rare, and many of the obstacles to implementation that we observed with the Plan are shared elsewhere. We see four main contributing factors:

1. Management latitude on adaptive management areas was limited.
2. Some people saw adaptive management only as a public participation process to test collaborative goals that were included in the Plan.
3. Precaution trumped adaptation. Concerns with avoiding risk and uncertainty suppressed the experimental policies and actions needed to increase understanding and reduce uncertainty.

4. Regardless of good intentions, sufficient resources were not available to implement adaptive management as envisioned by FEMAT scientists or by the implementation team.

Successful examples of adaptive management occurred both in adaptive management areas as well as outside of them. Most evolved from successful researcher-manager partnerships, and some involved areas with a history of collaboration. These successes demonstrate that adaptive management is possible and suggest models for future consideration.

This report itself is an important step in the adaptive management approach adopted by the Plan. Even though most of the monitoring has been underway for less than a decade and many of its outcomes are expected to evolve over decades, the monitoring is already producing a wealth of data about the status and trends in abundance, extent, diversity, and ecological functions of older forest, the species that depend on it, and how humans relate to it. There is the expectation that monitoring findings will lead to changes in Plan implementation.

Synthesis of Monitoring Results

A critical part of adaptive management is monitoring one's progress toward a defined goal and then, based on these monitoring results, adjusting one's methods, if necessary. Below is a summarized synthesis of findings from the past 10 years of monitoring structured around four questions.

Has the Plan Resulted in Changes That Are Consistent With Objectives Identified by President Clinton?

The Plan's success cannot be fully determined in 10 years, but some trends are clear. The most notable successes are associated with protection of old-growth and riparian forests and associated species. Harvest of old trees and harvest in riparian areas is very low relative to historical harvest rates. Most existing old-growth stands are now protected from future harvest, and other middle-aged stands are slowly developing late-successional characteristics such as large trees. Watershed planning has improved; we have learned much about the distribution and habitat needs of sensitive species, and how to use silvicultural practices to accelerate old-growth development. Watersheds are being restored, roads decommissioned, and species protected by using site-specific, fine-filter approaches.

The Plan also fell short in some arenas, most notably in providing for a "predictable and sustainable level of timber sales and nontimber resources" and "new economic opportunities for year-round, high-wage, high-skill jobs." Specifically, timber harvests were lower than expected. Timber shortfalls resulted in economic hardship for some communities (severe in some cases), but others were able to compensate by increases in other economic sectors or through active civic leadership. Active fuel management in the fire-prone forest of the eastern Cascades and Klamath-Siskiyou regions has lagged behind expectations, perhaps increasing the risk of severe fire in these regions. In the last decade, large fires in some provinces resulted in substantial losses of old-growth forest and local increases in watershed degradation, but disturbance rates over the Plan area were consistent with expectations. The Plan was not entirely successful in ending "the gridlock within the federal government," although there have been noticeable increases in cooperation among federal agencies and between research and management.

Are Major Assumptions Behind the Plan Still Valid?

The Plan rested on many wide-ranging assumptions that were either explicitly identified within planning documents or implied through the direction and expectations of the Plan.

Many assumptions remain valid, such as the central assumption that old-growth forest was limited in distribution and that the network of reserves identified in the Plan would encompass most of the remaining old growth. Updated inventories are remarkably consistent with pre-Plan regional estimates of old-growth forest and reaffirm the assumed overlap of old growth and the reserve network. The network of late-successional reserves and congressionally reserved areas was also assumed to include most of the best remaining habitat for northern spotted owls and other old-growth-dependent species. Recent estimates identify 10.4 million acres of owl habitat in these areas, representing 57 percent of the habitat available on federal land. Improved modeling of murrelet habitat has produced similar estimates (81 percent), suggesting that the original planners successfully identified much of the nesting habitat on federal land.

In a similar context, key watersheds were identified as part of the aquatic conservation strategy. From an aquatic perspective, these watersheds were assumed to be in better condition than most. Aquatic monitoring demonstrated that key watersheds generally have fewer roads and higher rates of road decommissioning, thus they are judged to be in better condition. The Aquatic Conservation Strategy was designed by using science that emphasized the dynamic interconnections of riparian vegetation, large wood, sediment, and landscape disturbance. Subsequent research since the Plan's initiation has further strengthened the underlying assumptions of the strategy.

Monitoring results reinforce several other key assumptions of the Plan. For example, forest inventories clearly demonstrate that trees grow quickly in the productive soils of the Pacific Northwest. Increases in average tree diameter in undisturbed stands show that new, old-growth forests are being naturally produced, with clear future benefit for desired terrestrial and aquatic species. Experimental thinning in plantations demonstrated that some old-growth features, such as large trees and spatial heterogeneity, could develop more rapidly following treatment, whereas others simply require time.

The Plan assumed that reserve networks would be large enough to withstand large disturbances without loss of function. Thus far, that assumption seems to hold true. Whether fixed reserves are the best strategy for conserving biodiversity in the long term remains an untested assumption.

Several assumptions that were incorporated in the Plan have since proven to be unsupported or only weakly supported by new evidence or understanding. Assumptions were challenged regarding both socioeconomic and ecological relationships, with implications for both. One of the more important set of findings concerns the role of federal land. From a socioeconomic perspective, it was assumed that timber flow from federal land was a key determinant of community well-being. This turns out to be true in some communities, but not in most. It seems that social values have changed since the Plan's inception. For example, the planned harvest of old-growth forest in matrix areas or thinning older forest within reserves is now unacceptable to more people. This perceived shift drove changes in Plan implementation and had some unanticipated consequences; it increased remaining old growth and the risk of uncharacteristic fire and had positive and negative implications for species of concern.

Experience with the Plan has led to important changes in how ecosystem processes are viewed and the applicability of various conservation paradigms. For example, some consider the northern spotted owl as an umbrella species; they assume that conserving the habitat of northern spotted owls would provide for the needs of many other old-growth-dependent species. Results from the Survey and Manage program confirm that a single-species focus is effective for only a limited number of other species, and that more holistic strategies are required. Recognizing barred owls and West Nile virus as potential threats to northern spotted owls demonstrates that providing habitat is a necessary but not sufficient condition for conserving species. Researchers increasingly recognize that disturbance is an important component of ecosystem productivity and biological diversity, and that positive long-term benefits can arise from episodic disturbances at a variety of scales.

Have We Advanced Learning Through Monitoring and Adaptive Management?

The monitoring program has produced a wealth of data that is starting to lead to changes in Plan implementation. Although there were some notable successes, there also were failures and places where improvements are needed.

In terms of new information, the major improvements in remote sensing and forest inventories provide a detailed picture of current forest conditions throughout the Plan area and provide the means for tracking changes in these forests. Similarly, species surveys and population monitoring aid understanding of the distribution and habitat needs of many species and provide indicators of change for select species. The northern spotted owl monitoring program is one of the most intensive avian population monitoring efforts in North America. The aquatic and riparian monitoring effort is systematically building a database on riparian and instream conditions that is amenable to both monitoring and exploring links among ecological drivers and responses at multiple scales. Despite its late start, the socioeconomic program has produced findings that illuminate the context of the Plan at a larger scale as well as its regional and local impacts.

There is room for improvement. Funding shortfalls and disagreements on design slowed implementation of the aquatic and riparian module. The marbled murrelet monitoring effort also took time to get underway, which limits the time series available for analysis. Inconsistencies between agencies and administrative units continue to impede integration of data in multiple ways. Improved record keeping describing management activities would enhance interpretation of outcomes and conditions.

In the last decade, many of the successful uses of experimental approaches have come from stand-level experiments such as variable-density thinning in plantations or combinations of prescribed fire and thinning in experimental forests. Rigorous experimentation at larger scales was rare. Our experience with adaptive management areas was generally disappointing, as they often did not facilitate the degree of innovation and experimentation expected.

Does the Plan Provide Robust Direction for the Future?

Invariably the question arises as to whether our observations of the past decade provide evidence that the Plan is or is not working and warrants revision. We contend that science alone cannot offer a definitive answer. Clearly, some expectations of the Plan have been met more successfully than others, but for most, it is too early or too difficult to judge. It ultimately depends on one's expectations, the value assigned to the various components and consequences, and one's beliefs about the possible performance of alternative strategies.

There are some areas where we can judge the progress that the Plan and federal agencies are making to address major management challenges. Our observations here are organized by the type of problem involved in a particular issue. That is, we look across the various issues and assess their similarities in terms of appropriate scale, temporal tradeoffs, or interactions between pattern and process. We conclude by examining the flexibility within the Plan.

Scale—

One theme that we have often repeated is the importance of the hierarchical nature of spatial and temporal scales. Every major issue has its own characteristic scale or mix of scales. A mismatch between the scale of a management response and the characteristic scale of the issue contributes to ineffective management. For example, as a broad-scale plan, the Plan's exclusive focus on federally managed lands makes it difficult to anticipate or assess the Plan impact without looking across the whole ecosystem. Many issues (economic effects, wide-ranging species like anadromous salmon and marbled murrelets, invasive species and wildland fire) do not recognize administrative boundaries.

In addition to transboundary problems, there also are spatial scale issues within the federal estate. There are the links between size and distribution of reserves and the purposes they are intended to serve, the role of complementary coarse-scale and fine-scale filters in species conservation, and the importance of managing within watersheds by looking across a range of stream sizes and upstream-downstream and upslope-riparian perspectives. Mid-scale planning would help match strategic direction from the Plan to an appropriate scale of action.

Temporal tradeoffs—
The questions of appropriate spatial scale are paralleled by issues of temporal scale. One pervasive issue is that of the tradeoffs between short- and long-term consequences. The issue is particularly acute when the short-term impact (or benefit) is highly probable but small in magnitude, relative to a less likely but more substantial long-term benefit (or impact). Temporal tradeoffs also are implicit in decisions regarding agency organization, staffing, training, and investment in research or learning. Just as physical infrastructure constrains management options, the same is true of social capital, agency technical capacity, knowledge, and technology. The reductions in agency workforce have affected the ability to plan and implement projects, and the reductions have affected rural communities, where federal workers may be among the more highly educated and influential residents.

Finally, there is the issue of having monitoring underway for less than a decade whereas many of its outcomes are expected to evolve over decades. Long-term trends are important to help us understand the variability about the status and trends in abundance, extent, diversity, and ecological functions of older forest, the species that depend on it, and shifts in human environmental values.

Pattern and process—
A third and perhaps most daunting set of problems in ecosystem management involve interactions between pattern and process and how they relate to resiliency in ecosystems. Similar to the issues of appropriate scale, pattern and process are intertwined concepts for describing, understanding, and managing landscapes—with a temporal twist. Pattern, the spatial arrangement of landscape components, is a consequence of process, the interactions between ecological components acting on a landscape. Just as pattern results from processes, processes are also constrained by pattern, but more than just pattern; other ecological components can be involved.

The challenges of understanding and managing spatial pattern and processes are present throughout the Plan, but nowhere more critically than in designating land allocations. The Plan may represent new thinking in resource management, but its primary mechanism is one of the oldest tricks in the book—multiple-use management by dominant use zoning and volume regulation for harvest scheduling. At the broadest scales, the Plan helps enable more intensive management on private timberlands while providing for higher levels of habitat conservation on public timberlands. Because of the Plan, the federal estate can be viewed as a collage of overlapping land-use designations, with each designation bringing its own set of standards and guidelines, and a second set describing which directions take priority. Thus a single landscape can have late-successional reserves, key watersheds, riparian reserves, congressionally reserved lands, adaptive management areas, and sundry other special-use designations. These are only the administrative boundaries. The real landscape has its own tapestry of natural features (for example, topography, soil, rainfall, stream networks, vegetation, fauna) intersecting with anthropogenic elements (for example, roads, farms, homes, cities, dams). The administrative designations are expected to dictate human activities that will work with natural processes and existing features to create a desirable landscape pattern of ecological attributes. Presumably, this pattern will constrain natural processes so the desired landscape is sustained for humans to enjoy.

The region affected by the Plan is an area of both remarkable similarities and pronounced differences. Traveling north to south or west to east within the Plan area reveals remarkable gradients in climate and topography, with resultant ecological variations in forest types and associated species. Equally remarkable are the socioeconomic differences between large metropolitan areas like Seattle, Washington, and Portland, Oregon, and the resource-dependent rural communities that are scattered throughout. Accommodating the intraregional ecological and socioeconomic diversity has been a major challenge to those designing and implementing the Plan. Opinions differ on whether or not the Plan intended for considerable discretion to adapt standards and guidelines to provincial or site-specific differences, but there appears to have been a reluctance or resistance to change default standards and guidelines. The flexibility allowed and willingness to use it are essential to matching management actions to local conditions and improving efficiency. Exercising discretion is a standard approach to managing risk. Flexibility can also allow for greater experimentation, and hence enhance opportunities for learning.

The Plan represents an ambitious, long-term vision for managing federal lands of the Pacific Northwest, but it remains to be seen how well it can adapt. Carrying the vision forward by building on the successes of the Plan and improving its shortcomings promises to be a continuing challenge. Changes in social expectations and values, administration policies and procedures, and other socioeconomic factors will play out in unforeseen ways. Equally important are the inevitable ecological surprises such as large-scale disturbances, invasive species, droughts, disease, and climate change that will strain ecosystem resiliency and potentially lead to major shifts in forest communities. In an era of declining federal funding and personnel, management agencies will be further challenged to improve partnerships and collaboration in order to leverage limited resources to meet growing societal demands. The only prediction that we can make with certainty is that information, knowledge, and creativity will always be essential ingredients for effective and adaptable forest management.

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We thank Martha Brookes who edited many of these chapters and who challenged all of us to express our thoughts both more clearly and concisely. We thank the many chapter reviewers and John Laurence, Russ Graham, and Doug Ryan for their constructive comments. We thank Rhonda Mazza for her help in compiling the summary and abstract. We thank Judy Mikowski for helping track the various chapter drafts and compiling the complete drafts for two rounds of reviews. We thank Margaret Hamilton for her assistance in handling administrative and financial tasks.

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Contents

Part I

Chapter 1: Objectives of Northwest Forest Plan Synthesis

R. James Barbour, Richard W. Haynes, Rachel White, Bernard T. Bormann

Origins of the Northwest Forest Plan

In the early 1990s, public controversy over timber harvest in old-growth forests of the Pacific Northwest, the decline of the threatened northern spotted owl (see appendix for scientific names), and habitat protection for Pacific salmon populations brought the forest management community to a crossroads. Would management of both public and private forests continue to emphasize production of timber and other commodities, or would public land managers focus more strongly on environmental priorities? This dilemma would not be the first to confound management direction for public lands in the Western United States. Nor would it be the first time change was controversial.

By fall 1992, injunctions by federal courts (for example, Judge Dwyer's decision in Spring 1991)[1] on harvest of federal timber within the range of the northern spotted owl and marbled murrelets had thrown the region into turmoil. Those who argued for the ecological health of the forests were in direct opposition to those who argued for the economic and social benefits of a thriving timber industry. The result was a polarized impasse, and without a basis for a legislative solution, the issue rose to the level of Presidential politics. Shortly after taking office, President Clinton fulfilled a campaign promise to the people of the Pacific Northwest and called a forest conference in Portland, Oregon, in 1993. The conference ended with President Clinton issuing a mandate for federal land management and regulatory agencies to work together to develop a plan for resolving the conflict between timber and other resource values. This would eventually lead to the creation of the Northwest Forest Plan (the Plan), a massive and unprecedented effort to find a legally binding, socially acceptable,

Forest conference 1993.

and scientifically-based solution for forest management. It represented a tremendous commitment of resources, and it necessitated redirecting the regional impasse toward a systematic compromise.

To guide the process, President Clinton listed the following five principles, which reflected an evolving set of core values and attitudes about how to manage the Nation's public lands to provide a balance of ecological and economic goods and services (FEMAT 1993):

> First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can preserve the health of forest lands, [timber] sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs.
>
> Second, as we craft a plan, we need to protect the long-term health of our forests, our wildlife, and our waterways. They are a…gift from God; and we hold them in trust for future generations.
>
> Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecologically credible, and legally responsible.

[1] 1994. U.S. District Court. Seattle Audubon Society and others v. John L. Evans, Washington Contract Loggers Association and others.

Fourth, the plan should produce a predictable and sustainable level of timber sales and nontimber resources that will not degrade or destroy the environment.

Fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you. We may make mistakes but we will try to end the gridlock within the federal government and we will insist on collaboration not confrontation.

Richard Haynes

Humans are among the species who depend on the forest for habitat. Each housing unit uses 6,000 to 8,000 board feet of lumber

What Exactly Is the Plan?

The Plan is a complex set of policies, decisions, standards, and guidelines. Because no single source contains it entirely, what constitutes the Plan is a source of confusion.

Following the forest conference, the White House assembled a team to begin working on the plan envisioned by President Clinton. The resulting Forest Ecosystem Management Assessment Team (FEMAT) developed 10 management options that were translated by managers into a supplemental environmental impact statement. In July 1993, Clinton announced the selected option (option 9), and used it as the basis for a report titled "Forest Plan for a Sustainable Economy and a Sustainable Environment." The forest management and implementation portion of this strategy was released as a record of decision (ROD) in 1994, which amended the planning documents of 19 national forests and 7 USDI Bureau of Land Management (BLM) districts (USDA and USDI 1994). We define this record of decision, with its published standards and guidelines, as the Plan. It caused sweeping changes in the management of federal forests in northern California, western Oregon, and western Washington. It encompasses 24 million acres of federally managed land within the more than 50-million-acre range of the northern spotted owl. It is based on some basic principles of conservation biology (see chapter 7), while also recognizing that in dynamic landscapes some active management might be necessary to achieve goals (see chapter 6). Another important aspect of the Plan to keep in mind is that it is not strictly a scientific plan. It also represents a political and social compromise, and, as such, it contains facets that do not adhere to any scientific theory. Needless to say, the scale of the Plan presents unique challenges in ecosystem management, adaptive management, and monitoring. What happened as the Plan was implemented did not necessarily reflect its directives. Thus, in the chapters that follow, we refer to what actually happened during the implementation of the Plan.

As stipulated by the Plan, the federal land base was allocated among a network of connected reserves with both terrestrial and aquatic components embedded in a matrix of "working" forests (fig. 1-1). Management objectives differ by land-use designation, as explained below.

Connected Reserves

With the intention of maintaining connected late-successional and old-growth ecosystems across federal lands, a system of late-successional reserves (LSRs) and riparian reserves was delineated. Late-successional reserves were designed to maintain well-distributed habitat on federal lands for the threatened marbled murrelets and northern spotted owls. The riparian reserve network was intended to reverse habitat degradation for at-risk fish species or stocks, and to serve a terrestrial function by providing a system of

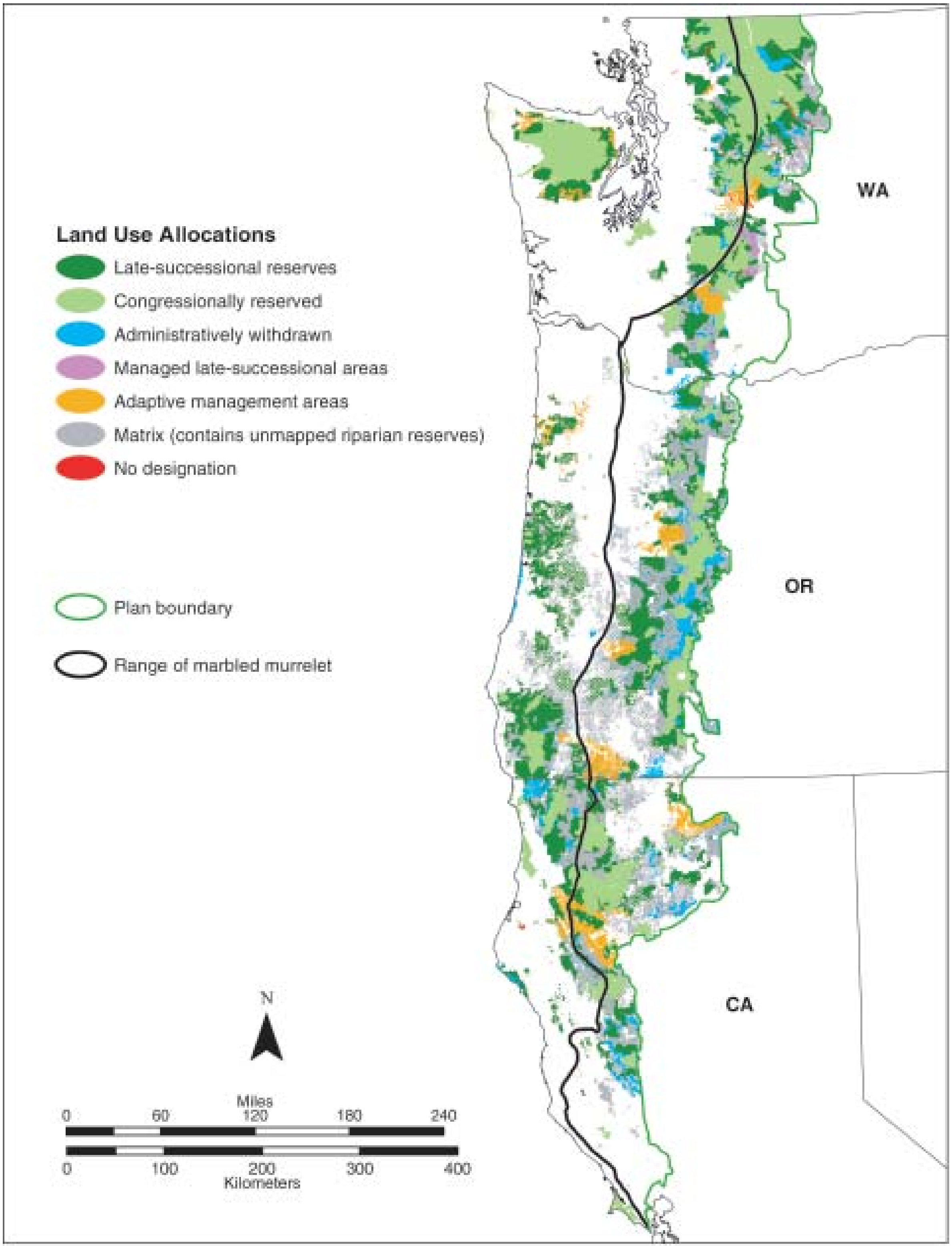

Figure 1-1—Land use allocations designated in the Northwest Forest Plan (Plan).

old-forest structural elements to connect the LSRs.[2] By creating sufficient habitat for plant and animal species thought to be closely associated with late-sucessional forests, the FEMAT scientists and the managers who wrote the ROD hoped that the Plan could avoid the need to establish new single-species management plans as mandated by the Endangered Species Act (ESA) for additional late-succession-associated species. The design of the connected reserve system was constrained by at least three factors: (1) the location of the remaining pockets of old-growth forest, (2) the locations of "key watersheds" identified by the FEMAT aquatics team, and (3) the portion of the landscape controlled by the federal government.

Matrix

The implementation of the Plan attempted to balance the economic, environmental, and social challenges facing a broad region. Socioeconomic effects were estimated for different land management strategies and were the basis for extensive public debates (FEMAT 1993). Matrix (all federal land outside of reserves and withdrawn areas) was a key feature in addressing the economic hardship faced by workers, businesses, tribes, and communities affected by reductions in federal timber harvests. Land designated as matrix was envisioned as the source of commodities, particularly timber, promised under the Plan. At the time the Plan was instituted, the timber industry provided the only year-round employment in many rural communities. A substantial number of the mills in those communities depended on timber from federal lands, and most rural counties within the Plan area relied on payments in lieu of taxes from the federal government that were based on timber receipts. Ecologically, matrix would provide early- and mid-seral habitats that would become scarce within the reserves. Matrix was also intended to provide forested cover between the late-successional and riparian reserve networks.

[2] This system was influenced by the work of Harris (1984) who applied island biogeography theory to develop a management scheme that would link preserves in an archipelago of habitat islands allowing for the movement of wildlife among them.

Adaptive Management Areas

Because the Plan was designed as a dynamic plan that would change as new knowledge came to light, adaptive management areas (AMAs) were created as places where new ideas and concepts for management could be tested. The Plan's emphasis on managing ecosystems, linking scales, monitoring, and adaptive management make it unique. At the time it was established, it was probably the only large-scale plan that included all of these concepts. Inclusion of learning opportunities as an integral part of the Plan recognizes the limits of scientific understanding and management experience in manipulating forest ecosystems. In theory, it provides a way to confront uncertainty and risk—ultimately improving the quality of natural resource decisions by combining trials of new ideas with monitoring, then allowing for change where necessary.

One of the innovative aspects of the adaptive management system was that it encouraged a localized, individualistic approach—as opposed to uniform, "top-down" guidance. Intended to allow managers flexibility and opportunity to adapt practices to local circumstances, this approach may have led instead to some of the implementation difficulties that would plague the AMAs in the coming decade. Rather than embracing this "freedom," some managers may have interpreted the approach as a lack of organizational support (Stankey and Shindler 1997). Without clear expectations as guidance, some AMA programs suffered from neglect.

The Inner Workings of the Plan: Monitoring

This report focuses primarily on monitoring. Monitoring is required by the ROD (USDA and USDI 1994), and adaptive management is absolutely dependent on it. It is also mandated under applicable laws and regulations (for example National Forest Management Act of 1976 [NFMA], Federal Land Policy and Management Act of 1976 [FLPMA], and the Endangered Species Act of 1973). Furthermore, Judge William L. Dwyer (see footnote 1) stated, "Monitoring is central to the plan's [Northwest Forest Plan] validity. If it is not funded, or done for any reason, the plan will have to be reconsidered."

The strategy and design of the effectiveness monitoring[3] program for the Plan was initially approved by the Regional Interagency Executive Committee (RIEC) in 1995. Because the Plan did not describe how monitoring should be done, it took several years and many participants to finally publish a monitoring framework (Mulder and others 1999), which was approved by the RIEC in 2001. The objectives of this monitoring framework are to:

> "Evaluate the success of the Northwest Forest Plan in achieving the objectives on federal lands of:
>
> a. Conserving late-successional habitat and related species.
>
> b. Improving watershed condition.
>
> c. Providing resource production and assistance to rural economies and communities."

Federal agencies assigned specific resources to be monitored, to gauge whether these objectives were being met (Mulder and others 1999). Implementation monitoring by Provincial Advisory Committees began in 1996. Northern spotted owl population monitoring, which began well before the Plan, was adopted as a component of the overall monitoring module (Lint and others 1999). Monitoring protocols for marbled murrelets (Madsen and others 1999), late-successional old-growth (Hemstrom and others 1998), watershed condition (chapter 9), and tribal consultation (Crespin 2004) have been approved and implemented. Methodology for socioeconomic monitoring, possibly the most challenging of all the monitoring activities, continues to be tested and evaluated (Charnley and others 2006, Sommers 2001, Sommers and others 2002). Methods for monitoring biological diversity and methods for validation monitoring have not been established.

[3] The Plan recognizes three distinct types of monitoring: (1) implementation monitoring, which is used to verify that mandated or agreed-upon activities actually take place; (2) effectiveness monitoring, which is used to establish that mandated or agreed-upon activities actually accomplish the desired goal; and (3) validation monitoring, which evaluates alternative ways (perhaps more efficient ways) to accomplish desired goals.

Objectives of the 10-Year Synthesis

The purpose of this document is to review the first 10 years of the Plan and reflect on what has been learned—from monitoring and research—to inform future management directions for federal forest lands in the Pacific Northwest and northern California.[4] This report takes the notable step of initializing the closing of the adaptive management loop—completing a cycle of planning, acting, monitoring, evaluating as a basis for subsequent planning, and modifying implementation as appropriate. Such a closure has rarely been accomplished before, at least on a regional scale. Authors of the various chapters will point out what worked and what did not, identify what has changed over the Plan's first decade, and discuss how new information or unexpected events might influence the future functioning of the Plan.

In focusing on how well expectations of the Plan were met, we recognize that expectations are based on values, and that societal perspectives shift and flow. Natural

Judy Mikowski

Wildlife viewing is one of the most rapidly growing recreation activities, and development of sites offers an opportunity for agencies to interact with the public.

[4] This is not the first time we have attempted to synthesize the science aspects of the Plan. Haynes and Perez (2001) summarized what was learned, what were the new insights, and how these insights affected the direction of Plan-related research.

resources are human conceptions, and complex shifting values surrounding these constructs (often oversimplified into polarities like "owls versus jobs" or "economy versus ecology") are eventually reflected in natural resource policy (Clark and others 1993). As we review the Plan, we attempt to remain as objective as possible by highlighting the perspectives and worldviews that framed its creation and implementation.

Although President Clinton outlined an array of societal, ecological, and organizational principles to direct FEMAT, researchers were instructed to consider ecological values first, before other societal values (FEMAT 1993). This ecological-values-first approach was a policy decision, not a science one, and reflects the fact that forest management is inherently a political undertaking (Clark and others 1993). Meanwhile, perspectives have continued to evolve. For example, international agreements on sustainable development now focus on balancing ecological and social values. Other regional assessments have also adopted a codominant, multiple-use perspective (Quigley and others 1996). In general, we interpret Plan performance by using the ecological-values-first perspective.

We begin convinced that 10 years is not enough time to answer many of the relevant ecological questions. The ecological processes the Plan was intended to influence or protect play out over centuries and millennia. Even so, after 10 years we can discern whether some of these processes appear to be on the right track or are spinning off on unanticipated trajectories, although any conclusions are only provisional. Such inferences can only be made by using a combination of empirical data—where available—and the collective knowledge and experience of scientists and resource managers familiar with ecosystems covered by the Plan. For nonecological issues, sufficient time has passed to determine whether some of the principles President Clinton spoke of at the Portland forest conference in 1993 have been followed. For example, we can evaluate how the Plan has influenced social systems, and assess whether this influence matters to economic conditions in the region. We can speak to the success of establishing monitoring programs. We can also determine if federal agencies really work more closely together then they did in the 1980s. Finally, we can discuss the success of the adaptive management process.

Uncertainty and Complexity

Two themes have evolved that will reappear throughout this report, one involving the complexities of scale, and one involving uncertainty. The concept of scale comes into play in both a spatial and a temporal context. Spatially, we think of scaling as the way vegetative structures and patterns are arrayed across the landscape from very small patches (less than an acre) to large blocks that could conceivably cover whole watersheds. Temporally, processes like fire could occur over a few hours or days, whereas development of old-growth structures could take a century or more. Dealing with scale becomes quite difficult when contemplating multiple ecological and social values that occur over different spatial elements and temporal frames. Integration of planning and implementation of management across federal agencies (each with a history of acting independently on site-specific activities) further complicates the issue.

We also highlight uncertainties that influence how we interpret what is and what is not known. We discuss the variability, adaptability, and interdependency of natural and social systems as the basis for uncertainty, and contemplate what managers might consider in response. Specifically, our experience has emphasized the importance of recognizing there is a continuum of forest conditions and stages. For example, during the past decade we have seen rapid evolution among stakeholder groups' different definitions for old-growth to the point that contemporary definitions (stands of natural origin greater than 100 or 120 years) have little scientific basis. We have seen similar ambiguity in the definitions and specifications of the term "reserve." The Plan calls for a system of connected reserves; however, in developing this approach, insufficient attention was given to both the implications of a highly dynamic landscape and what flexibility could be considered after broad-scale disturbances. For example, the framers of the Plan anticipated that fires would occur, especially in the drier provinces. They did not, however, anticipate the size, number, or placement of the fires that did occur. Some events, like the range expansion of barred owls, were completely unanticipated.

Both management and science experience suggest that the complexities of ecosystem management and uncertainties of both internal and external processes and events can confound the best-laid plans. Contributing to these complexities and uncertainties are the role of private lands in meeting Plan intentions, the influence of lands and systems like headwater streams that had not been considered as part of the habitat for selected species, the implementation of a multiscale plan where little attention was focused on midscale planning, the role of disturbances, and differences in how federal agencies approached Plan implementation. Given these limitations and inevitable information gaps, asking whether expected responses were reasonable and whether solid conclusions can be expected in just 10 years are fair questions.

Looking Ahead

We acknowledge that some emerging issues are likely to challenge both scientists and managers in the coming decade in areas where we can only offer scant information. These issues include such questions as: How does climate change impact the effectiveness of the Plan as a risk management strategy? To what extent can hazardous-fuel reduction treatments (undertaken in the context of the Healthy Forest Restoration Act [HFRA] of 2003) be conducted in matrix stands or in LSRs in the Plan's drier areas? What are the unintended social and economic consequences of implementing the Plan and where will they manifest themselves? What are the ongoing changes in societal values that will shape the next round of plans for USDA Forest Service (FS) and BLM management? To what extent are the Plan's ecosystem management approaches consistent with approaches to sustainability being enhanced by land managers in North America? How sustainable is the Plan, given the increases in demands for ecosystem goods and services as human population increases? How can strategies for managing invasive species be applied in the Plan area?

Our Goal: To Inform the Debate

On the world stage, the Plan is recognized as a unique undertaking in the world forest management community. The Plan's emphasis on partnerships among scientists and resource managers, ecosystem approaches, linkages among scales, monitoring, and on institutions for coordinating and using adaptive management practices are all distinctive. The Plan combined a variety of tactics, such as an economic adjustment initiative to provide temporary support to people whose jobs were affected by changes in land management strategies. Looking back over the past 10 years offers an unusual opportunity for a broad-scale examination of the effectiveness of such programs intended to mitigate social and economic impacts of the Plan.

To a large degree, the chapters that follow are written by scientists who participated in FEMAT (1993), which provided the scientific foundations for the Plan. They have also provided guidance on the Plan's monitoring modules. Consequently, they bring a unique point of view to this document. Some might argue that they have been too close to the process and therefore cannot possibly provide an unbiased evaluation. Others would say that because they have been so close to the process, only they can offer the kinds of insights provided here. One thing is certain: this document probably represents the last time this group will assemble as a unit to write in such detail about the Plan, because although 10 years is not a long time in the life of an old-growth forest, it is in the life of a scientist. The controversial issues that necessitated President Clinton's forest conference in 1993 are part of the same debate that has been with us for over a century and is still with us today. In presenting the information, ideas, and perspectives in this report our goal is simply to better inform that debate.

The report is organized as follows:

Part I

Chapter 1: Objectives of the Northwest Forest Plan Synthesis. Provides an overview of the Plan's origins, describes its principles and land-use allocations, discusses its monitoring module, and outlines the objectives of this synthesis report.

Chapter 2: Context for the Northwest Forest Plan. Reviews the context leading to the Plan, including the philosophical and legal basis, background information on the environmental movement and the timber industry, and the differences in agency culture. The chapter concludes by reflecting on the continually shifting nature of the context for managing federal forests.

Chapter 3: Synthesis: Interpreting the Northwest Forest Plan as More Than the Sum of Its Parts. Considers the Plan by examining all findings together, by looking at changes in the last 50 years to gain the perspective of time, by examining some general management principles, and by looking forward through opportunities to address three major management issues, contingent on the desired balance of ecological and commodity values.

Chapter 4: Progress to Date. Discusses measurable progress, validity of assumptions, and advances in learning as a basis for looking to the future. We explore appropriate scales, tradeoffs through time, and links between processes and resulting patterns, and end with a discussion of future flexibility.

Part II

Chapter 5: The Socioeconomic Implications of the Northwest Forest Plan. Summarizes how well the Plan met the socioeconomic needs outlined in the President's principles and discusses several unexpected changes in community stability, timber markets, and the role of nonfederal lands. It also takes on issues of sustainability and multiagency decisionmaking.

Chapter 6: Maintaining Old-Growth Forest. Reviews what was expected for, and what happened to, older forest, and details understandings that have developed since the Plan was written. This chapter explores the effects of disturbances on the reserve system, uncertainties such as climate change, and the controversies with postfire salvage in reserves. Much of the discussion is based on the idea that biodiversity can be managed by managing for ecosystem characteristics. The chapter ends with a range of reserve strategies contingent on the desired balance of ecological and commodity values.

Chapter 7: Conservation of Listed Species: The Northern Spotted Owl and Marbled Murrelet. Reviews changes in owl and murrelet populations and habitat, sources of uncertainty, validity of assumptions, and new research findings.

Chapter 8: Conservation of Other Species Associated With Older Forest Conditions. Explores viability analysis, lessons from the Survey and Manage program, and the effectiveness of the reserve system.

Chapter 9: The Aquatic Conservation Strategy of the Northwest Forest Plan: An Assessment After 10 Years. Reviews the aquatic conservation strategy central to the Plan and the available findings from aquatic-system monitoring, and examines new research findings, checking for consistency with the conservation strategy. It also discusses new ideas about ecosystem dynamics, the role of fire in riparian reserves, and problems with managing at both small and large scales.

Chapter 10: Adaptive Management and Regional Monitoring. Examines the processes of adaptive management and regional monitoring used to achieve Plan goals and to direct change over the long term. Also discusses uncertainties related to the precautionary principle, learning strategies, and issues surrounding linking what was learned to changes in practice. Finally, the authors suggest ways to improve adaptive management and monitoring.

Part III

Chapter 11: Key Management Implication of the Northwest Forest Plan. Part III was written by a team of employees from the USDA FS, USDI BLM, and US Fish and Wildlife Service. It reflects their review of early drafts of Parts I and II as well as extensive discussions of the intent of Plan implementation, the ensuing management actions, and implications for future management actions. They also discuss the desirability of reexamining the goals for the Plan in light of emerging science findings and resource conditions.

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Chapter 2: Context for the Northwest Forest Plan

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Introduction

Although set in the Northwest, the issues at stake in the Northwest Forest Plan (the Plan) are much broader—and much debated. The balance President Clinton described between utility and protection when charging federal agencies to develop the Plan (see chapter 1) has been sought after for more than a century. In 1890, with the closing of the American frontier, came the realization that the Nation's resources were finite; from that point on, debate has circled around virtually every management decision relating to land in the public domain. This debate has often centered on "Should this land be viewed primarily as a source of economic opportunity, or as a national treasure to be preserved untouched?" During the past century, legislation associated with this debate has created the USDA Forest Service (FS), the USDI Bureau of Land Management (BLM), the National Park Service (NPS), the Fish and Wildlife Service (FWS), and several smaller federal land management agencies to administer public lands in the Western United States.

Our task in this chapter is to briefly review the historical, philosophical, and political contexts leading up to the Plan, and to address the continually shifting nature of social movements and land management debates. Two commentaries on the establishment and objectives of the Plan that are particularly useful in this respect are those by Tuchmann and others (1996) and Pipkin (1998). These commentaries are especially insightful because their authors were key players in implementing the Plan. Pipkin's report discusses the genesis of the Plan, its achievements, some of the lessons learned, and organizational changes resulting from it. Tuchmann and others (1996) provided a brief overview of the political and management histories of federal lands that set the stage on which the creation of the Plan was eventually played out. They also discussed the evolution of social awareness and expectations for land in the public domain, which has been reflected in corresponding federal legislation, and has continued to inspire debate as to the appropriate role of government in managing public lands. We dig a little deeper into the laws associated with different phases of public perception to provide context for the discussions in subsequent chapters about the different types of monitoring that have been performed under the Plan, and whether the Plan is meeting society's expectations. Note that although the Plan is based in science, it was and still is a political, not a scientific, document (FEMAT 1993). Thus its power comes from the legislative and legal system, not the scientific literature. As Judge Dwyer said when he issued his final ruling on the Plan, "It does not matter whether this is the best plan, it only matters that it fulfills all of the legal requirements."

Public Perception and the Role of Government in Land Management

Up to and through the last half of the 19th century, disposal of public land was a primary objective of federal land law and policy. In fact, public lands presented a managerial burden to the federal government, which saw them as redeemable only through settlement, cultivation, and profit. Providing land as an incentive for settlement (such as homesteading) or development (such as railroads) was seen as a way to "conquer" the wilderness and claim dominion over the West. To best encourage this empire-building "redemption" of the land, the most desirable public land was disposed of first. In the mountainous West, this meant the lower elevation areas and flatter valleys that contained the most productive timber stands or rangeland and were most suitable for agriculture. That these areas largely ended up in private hands would one day dictate the management options available to public agencies as the Plan was designed.

As civilization made increasing inroads into the Nation's wild areas, the end of the 19th century also saw the rise of the conservation and preservation movements (Hays 1959). George Perkins Marsh's (1864) description of the transformation of the environment as a feature of human history and the role that clearing of forests played in human development influenced the evolution of these movements. Conservationists, such as Gifford Pinchot and Theodore Roosevelt, believed that natural resources should be managed to provide a sustainable source of wealth and national prosperity. On the other hand, John Muir, representing preservationists, believed that wild places should be set aside to be entirely protected from human hands. In the formulation of the differing viewpoints held by those like Muir and Pinchot, the separation between conservation and preservation was born. And as these movements gained momentum, federal legislators began to recognize the merit in retaining management control over more and more federally administered land. This realization came in fits and starts, however, and was applied differently to different parts of the federal land portfolio. What follows is a brief look at how the creation of various land management agencies dealt in different ways with defining the role of the government in administering public land.

The Creation of the Forest Service

In 1897, the Organic Act created new forest reserves totaling more than 21 million acres to protect the sources of the West's water, manage grazing, and regulate timber harvest. The forest reserves were transferred to the FS in 1907 and became the backbone of the national forest system.[1] These events were intended to regulate the use of federally administered lands, with the twin goals of protecting natural resources and providing economically valuable commodities. As Gifford Pinchot envisioned it in his autobiography, the creation of national forests should provide the greatest good for the greatest number of people (Pinchot 1947). Pinchot's vision of how to manage these forests came through strongly in his autobiography, especially when berating preservationists who wanted to save every tree: "Their eyes were closed to the economic motive behind true forestry. They hated to see a tree cut down. So do I, and chances are that you do too. But you cannot practice forestry without it" (Pinchot 1947). (In contrast, Muir had little faith in human intrusions on forests and wilderness: "Unless reserved or protected, the whole region will soon or late be devastated by lumbermen and sheepmen, and so of course made unfit for use as a pleasure ground" [Muir 1912].) In keeping with the ethic of the conservation movement, the creation of national forests resulted in greater federal control, although national forest managers generally followed an extensive, low-level management model. Forest managers have maintained an enduring belief that society values its national forests more for their wildlife, water, and recreational opportunities than for commercial values such as timber or grazing (Kennedy and others 2005).

The Creation of the Bureau of Land Management

Although the BLM's mandate is now primarily one of management, its roots are very different from the FS mandate. The BLM can trace its origins to the General Land Office (GLO), which was created in 1812 to administer federal lands, and was eventually given the responsibility of disposing of them to encourage settlement and development. The BLM, the second largest land management agency associated with the Plan, was created through the merger of the Grazing Service and the GLO in 1946, but another 30 years passed before its mandate was clearly stated through that agency's own "organic" act, the Federal Land Policy and Management Act (FLPMA) of 1976. Through a combination of controversy, happenstance, and design, the BLM gradually increased its management role and decreased its disposal role. This new focus was reflected in changes in BLM's approach to forestry, which emerged in

[1] See Fedkiw (1998) and Kaufman (1960) for different historical perspectives on the USDA Forest Service history.

the 1970s as a multidisciplinary management program including recreation, wildlife, grazing, watershed, and cultural resource programs.

Explaining the evolution of BLM's forestry program involves going back to one of BLM's predecessors, the GLO. In 1937, the Oregon and California Revested Lands Sustained Yield Act (O and C Act) had restored federal ownership of about 2.7 million acres of forest land in western Oregon by giving it to the GLO. A key feature of the O and C Act was its stipulation that management of the O and C lands, some of the best timber stands in the United States, would help support the economic well-being of communities in the O and C area and provide a substantial portion of timber revenues to the counties within these lands (Muhn and Stuart 1988). The BLM inherited the O and C lands, and their mandate, when it was created in 1946. Timber production became politically important to the BLM as it recognized the importance of these lands (which make up most of the timberlands currently managed by the agency) to the economic well-being of many local communities (Muhn and Stuart 1988). Decades after the O and C Act, its consequences would play a large role in both providing land for the Plan, and creating controversy about the Plan's design and implementation because of the expectation of sustained timber yields and revenues to counties.

The Creation of the National Park Service and Fish and Wildlife Service

The NPS and FWS are the other two federal agencies that manage substantial acreages within the Plan area. Their histories and mandates are quite different than those of the FS and BLM. Both NPS and FWS have their roots in the preservation movement of the late 19th and early 20th centuries. The NPS's beginnings stem from the preservation of the 2 million acres of beautiful and geothermically unique land of Yellowstone National Park in 1872. By 1916, when 19 national parks and 21 national monuments had been created, the preservationist role of the agency had been fairly well defined (Clarke and McCool 1985). Although it is possible to trace the lineage of the FWS back to 1871, it has only existed in its current form since 1970 and does not have an organic act describing its role (Clarke and McCool 1985). The FWS has a dual mandate of management (for national wildlife refuges), and regulation through its consultative role under the National Environmental Policy Act of 1969 (NEPA). Together with other regulatory agencies like National Oceanic and Atmospheric Administration Fisheries and the Environmental Protection Agency, it provides oversight of Endangered Species Act (ESA) reserves in environmental assessments (EAs) and environmental impact statements (EISs) prepared by management agencies as part of their planning. The management roles of NPS and FWS (at least for refuges) have not changed materially since their inception.

Agency Culture and the Plan

An important concept for contextualizing the formation of the Plan is that the mandates of the various federal agencies responsible for managing and regulating federal lands within the Plan area have evolved at different rates and in different directions over the past two centuries. This disjunction has created distinct cultures within these agencies, causing friction during the establishment of the Plan, and presenting difficulties in fulfilling President Clinton's stipulation that the Plan help federal agencies work together. We think some notion of how these cultural differences arose is important to understanding the way the Plan has functioned over the past 10 years. At the same time we recognize that our interpretations will not be viewed as universally correct or even important by everyone who wants to evaluate the Plan.

The century-old debate over natural resource management has manifested itself in various ways in the formation of federal land agencies. The preservationist model, which values "nature untrammeled" and encourages management that sets aside land to allow natural processes to predominate, largely guides the management practices of the FWS and the NPS. In contrast, the conservationist model calls for management activities that manipulate forest structure to achieve outcomes desired by humans, whether the objectives are commodities or other environmental goods and services. Today, these management activities frequently are designed to mimic ecological processes. This conservationist line of thought has driven much of the management activity on FS- and BLM-administered land.

This is an important distinction which has probably attracted different sorts of people to the various agencies over the years. These differences in corporate philosophy were certainly a factor in development of the Plan, and they have influenced its implementation as well. Because of the dissimilar ways in which the agencies were established and structured, achieving interagency cooperation proved elusive–especially in the beginning of the forest planning process. For one thing, preexisting conflicts had to be dealt with before true coordination could happen. As one example, before the northern spotted owl (see appendix for scientific names) was listed as a threatened species in 1990, the FS and BLM were not required to consult with the FWS about management implications to owl habitat. Once the owl was listed, however, the agencies had to consult and address some highly complex issues–a process that greatly slowed their ability to reach decisions on things like timber sales (Tuchmann and others 1996). This lack of smooth coordination followed the agencies into the forest planning process. Along these lines, Jack Ward Thomas, who headed the Forest Ecosystem Management Assessment Team (FEMAT), related his frustration at the clash of agency objectives during negotiations over the Plan. He felt that the FWS was too single-minded in its emphasis on the northern spotted owl, and that this caused a stagnation of agency collaboration. "The situation with the Fish and Wildlife Service has been dragging on for nearly five years," he wrote. "They keep the Forest Service and Bureau of Land Management from any type of methodical approach to management of the forests of the Pacific Northwest" (Thomas 2004).

The Environmental Movement and the Plan

While the federal land management agencies were forming and gaining substance, the Nation continued to undergo transformations that shaped American society's thinking about the role of federal lands. After an initial wave of conservation successes that created 230 million acres of protected land (as 18 national monuments, 5 national parks, 51 national wildlife refuges, and 150 national forests), the Great Depression and then World War II sent conservation issues into the shadows as the Nation dealt with other urgencies and deprivations. When the war ended, a dramatic postwar boom propelled the Nation toward economic and social expansion. To fuel this expansion, demand for wood increased significantly, resulting in a change in management policy that shifted federal land management practices toward a timber production model resembling that used on industrial timber lands. This was particularly true in coastal Washington and Oregon.

After World War II, even as a more intensive industrial forest management model was being created, the American public began to recognize that timber harvest on public land potentially threatened other resource values. Quality of life was improving, with industry pushing forth a stream of new consumer goods, and Americans enjoying new amounts of leisure time and money. Along with this came a new appreciation for the natural world as a source of recreation and also as a source of fresh air and clean water—especially as rapid industrial growth began creating more and more pollution. The conservation movement reacted to these changes, evolving from the turn-of-the-20th-century emphasis on utilitarian resource-use policies into an emerging ecological awareness that perceived humans as part of the larger natural world. This perception recognized that human activities were putting heavy burdens on the fragile systems that support life. As it became a coherent new concept, "environmentalism" also became a potent force for change (Scheuering 2004).

Through the 1960s, 1970s, and 1980s, a steady progression of environmental legislation and regulations reflected the Nation's increasing environmental awareness. In 1964, the Wilderness Act gave impetus for preserving selective areas of high recreation or wildlife values. Many of the first congressionally designated wilderness areas were centered on primitive areas that had previously been set aside by the FS or BLM, but what was revolutionary about the Wilderness Act was it set aside land for no other purpose but its own preservation–showing recognition by the federal government that land had value even when left undisturbed. The Federal Water Quality Act (the Clean Water Act) was passed in 1965, the Clean Air Act in 1967, and the Wild and Scenic Rivers Act in 1968. When the groundbreaking NEPA was signed in 1969, it showed that even the Republican Nixon administration felt compelled to respond to the growing public demand for environmental regulations. By April 22, 1970—the first Earth Day—the environmental movement had truly arrived. Rachel Carson's *Silent Spring* (1962) and Paul Ehrlich's *The Population Bomb* (1968) were speaking to an increasingly informed and concerned public—and the Sierra Club had grown into a potent political lobby representing 78,000 members.

As society became better versed in ecological principles, its demands on federal land management agencies became more nuanced. The environmental agenda came to include an increasing interest in complex issues such as the restoration and conservation of biological diversity. During the early 1970s, the Endangered Species Act of 1973 (ESA), the National Forest Management Act of 1976 (NFMA), the 1976 FLPMA, and a variety of other laws and regulations documented these concerns for biological diversity on federal lands. Inevitably these changes in law and policy resulted in conflict between those interested in maintaining commodity production as a major, if not primary, objective for federally administered lands and those favoring noncommodity values. In fact, as the environmental movement gained power, it also mobilized its detractors.

The NFMA and FLPMA were born of the ideological concerns for the environment and increased interest in public involvement in government decisionmaking that characterized the 1960s and 1970s. They remain the principal statutes driving national forest and BLM planning today.[2] Although they did not change the multiple use and sustained yield focus of federal forest management, NMFA and FLPMA called for extensive planning and public involvement. The intent was to reconcile competing public demands at the scale of the individual national forest or BLM district. Congress recognized that conflicts among resource extraction, amenity values, and ecological issues such as biodiversity were an integral part of public land management. Rather than resolve such conflicts legislatively, Congress enacted a procedural planning process wherein it was hoped that a thorough and open analysis involving "integrated consideration of physical, biological, economic, or other sciences" would make possible local resolution of conflicts and wider acceptability of decisions. Each national forest, grassland, and BLM district was required to develop a land and resource management plan with the purpose of guiding all resource management activities for a 10- to 15-year period.

A key feature of the FS interpretation of NFMA was the inclusion of the "viability clause" in the 1982 forest planning regulations. This clause brought increased visibility and importance to species viability within forest planning. Section 219.19, Fish and Wildlife Resources, of the 1982 rule stipulates:

> Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area. For planning purposes, a viable population shall be regarded as one which has the

[2] Details regarding the FS planning process and the statutes that govern this process are readily available on FS Web sites. A useful starting point is http://www.fs.fed.us/forum/nepa/.

> estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area. In order to insure that viable populations will be maintained, habitat must be provided to support, at least, a minimum number of reproductive individuals and that habitat must be well distributed so that those individuals can interact with others in the planning area.

The viability clause would become a central factor in the legal battles that arose over the northern spotted owl and ultimately the design of the Plan. At about the same time, ESA mandated that species whose continued existence was threatened or endangered, and the ecosystems they depend on, would be given special management consideration. The NEPA required consideration of the cumulative effects of management activities at the project planning stage. The combination of NFMA, ESA, and NEPA and the regulations developed to enact them were effective tools for promoting conservation of biological diversity.

These regulations and guiding principles, which arose in response to social concerns and the increasing political influence of the environmental movement, set the stage on which the Plan took shape. Controversy arose when views over the appropriate role of the government in natural resource management clashed. The managers and scientists who developed the Plan attempted to deal with this public debate. They quickly realized that even the forest plans required under NFMA covered too small an area to effectively address regional issues; a larger landscape plan was needed to attack the viability question for northern spotted owls and marbled murrelets as well as the habitat needs of anadramous fish. They also realized that there was much that they did not know, and that the Plan would need to be versatile and open to change, especially considering the inevitable shifts and changes aligned with societal expectations.

Timber in the Pacific Northwest

It is not possible to consider the Plan in isolation from the timber issue: if not for this issue it is unlikely that any other human activity would have impacted forest structure enough to raise concerns about the viability of old-growth-associated species. The forest products industry in California, Oregon, and Washington has played a major role in the region—impacting both the region's economy and ecosystems in ways that are not usually apparent in other U.S. timber-producing regions.[3] Recognizing this, the Plan contained specific provisions that promised timber would continue to flow from federal lands. This guarantee of continued timber production was a key factor in making the Plan politically viable (Pipkin 1998).

The region's forest products industry developed as the demand for wood reached new heights during the post-World War II baby boom. From the late 1940s until the late 1980s, timber harvest in the Douglas-fir region increased roughly 25 percent, fueled mostly by increased harvest on public lands (see figs. 2-1a, 2-1b, data from Warren 2004). In fact, between 1945 and 1965, timber harvest on FS land in the western forests of Oregon and Washington rose from about 149 million cubic feet (745 million board feet) to 807 million cubic feet (4,035 million board feet) (Tuchmann and others 1996). Note that this was the same period that saw the rise of the environmental movement, which meant federal land agencies had to address the growing ecological concerns of the public at the same time that they were changing forest structural conditions to an extent that the West had not seen before. One way this happened was with the passage of the Multiple Use-Sustained Yield Act (MUSYA) in 1960 and the Classification and Multiple Use Act in 1964, which set the stage for adoption of management models by the FS and BLM, respectively, that were considerably different from the industrial model. They called for and defined sustained yield (of timber or other commodities) as "the achievement

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[3] Robbins in his two-volume Oregon environmental history (1997, 2004) described how the abundant forest resources and creative energies of Caucasian settlement led to a large industrial forest products industry that provided the livelihood for "dozens of small rural communities" and helped define the sense of place that frequently motivated Oregonians "to struggle with each other for the future of the lands and homes they loved."

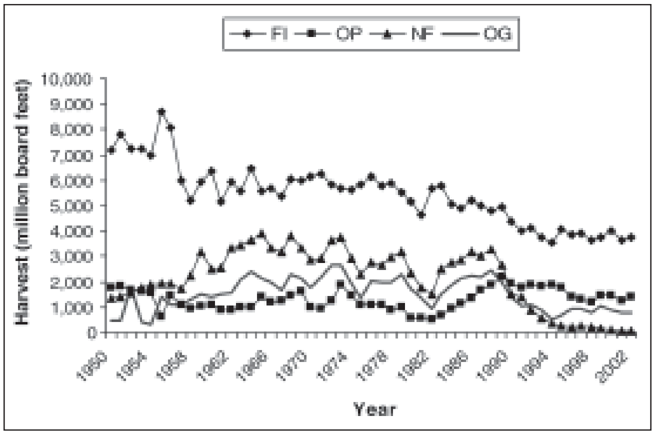

Figure 2-1a—Harvest for the Douglas-fir region (western Oregon and Washington), by owner. FI = forest industry, OP = nonindustrial private, NF = national forest, OG = other government.

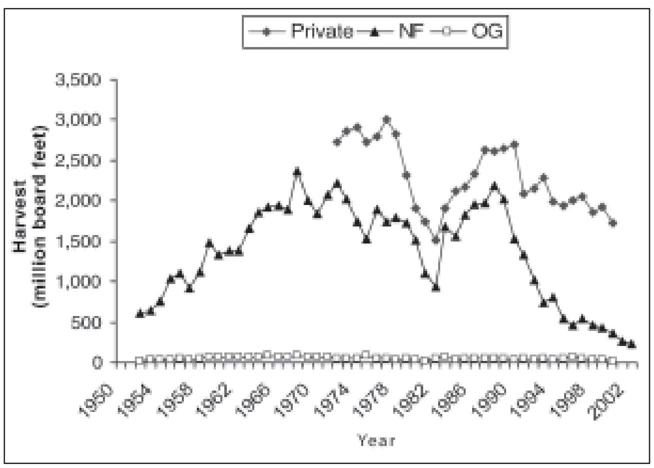

Figure 2-1b—Harvest for California, by owner. NF = national forest, OG = other government. Source: Warren 2004.

Robert H. Ruth

Staggered clearcuts were used starting in the early 1950s as harvest expanded on the national forests

and maintenance in perpetuity of a high level annual or regular periodic output." The ensuing implementation of the MUSYA led to the FS adopting (in 1973) a non-declining even-flow policy for harvest levels.

Meanwhile the forest products industry was expanding. The advent of mechanical processing made the use of abundant large-diameter timber feasible, and the development of inexpensive transportation systems encouraged delivery of products to the Eastern United States and east Asian markets. Rapid economic growth in Pacific Rim countries opened international markets to the coastal areas of the region and the log export trade grew rapidly (fig. 2-2), buoying stumpage prices. The rise and fall of the log export market would play a particularly important role in the management of the region's private timberlands and for state lands in Washington. Export markets favored larger, older, high-quality[4] trees. When the export of logs from federal timberlands was banned in the 1970s, it provided an incentive for private landowners to manage on longer rotations. This had the ancillary (and temporary) benefit of increasing the proportion of older forests (greater than 60 years) on some private lands, particularly nonindustrial private forest lands. Prior to the establishment of the Plan, however, effectively all of the old-growth forests on industrial private land and most of the old-growth on nonindustrial private forest land had already been harvested. In fact, the proportion of the private inventory composed of trees >160 years old dropped from 15 to less than 1 percent during the past 50 years.

A second consequence of the log export ban was that it created a plentiful resource domestically for large log mills that specialized in cutting public timber. But the design of the mills that purchased federal timber made it particularly difficult for them to adapt to major changes that would soon shape the industry. Particularly difficult for them to survive

[4] For Douglas-fir, this is usually seen as a mix of stem straightness, cylindrical boles, relatively small infrequent branches (or no branches in older trees), and high stiffness compared to other softwoods.

Dean Parry

A California black oak log being sawn at the headrig in a mill in Northern California. The headrig is a horizontal bandsaw, common in mills capable of sawing large logs.

Dennis Dykstra

Northwest sawmills have embraced new technologies to stay competitive. Here a worker is running edger line in an automated small-log mill.

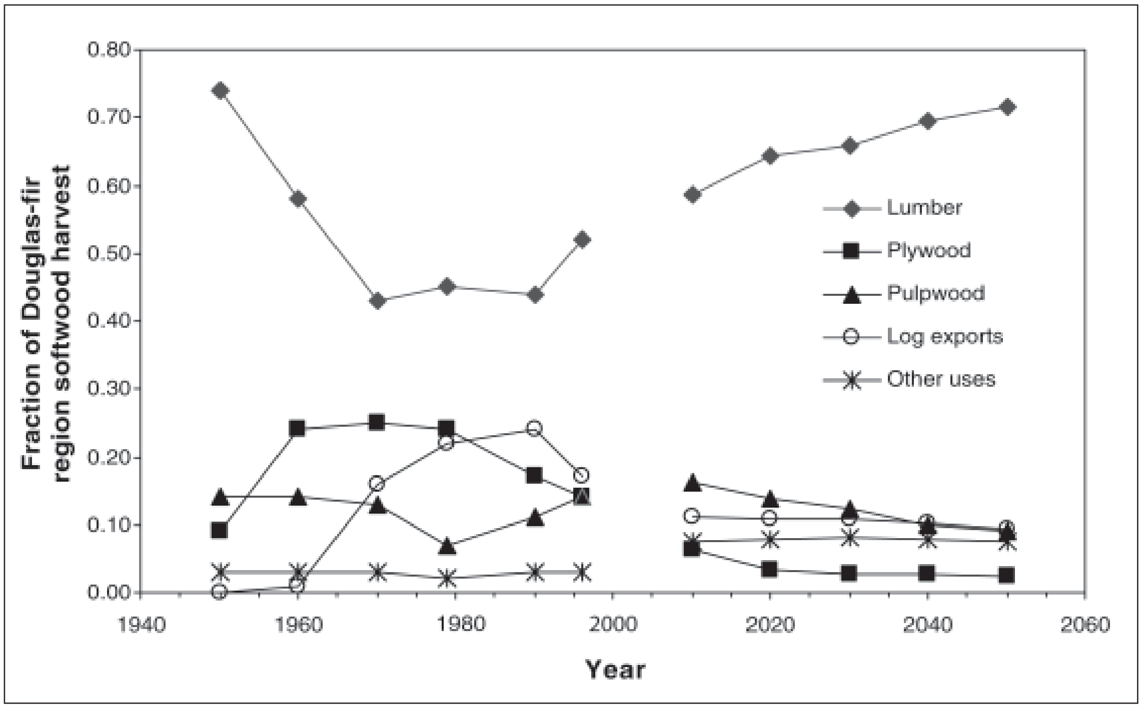

Figure 2-2—Proportions of the Douglas-fir region (western Oregon and Washington) softwood harvest by product category: history and projections from 2000 Resources Planning Act timber assessment. Source: Haynes 2003.

were the injunctions on the sale of federal timber that occurred just prior to the implementation of the Plan, which caused wood supplies to fall below existing processing capacity. For mills that were dependent on federal timber, size also mattered: by and large they simply could not efficiently process smaller logs. For these reasons, through the early 1990s these large log mills closed their doors. When the Asian economic collapse hit in the mid-1990s the region's capacity to process logs larger than about 20 inches was mostly gone. Private landowners who tried to shift sales of export-quality logs into the domestic markets found that rather than the premium they had come to expect over the past quarter century, these logs were now discounted. The result has been an inevitable shift toward forest management regimes that favor shorter rotations (fig. 2-3). Today the economic incentive for all private landowners is to grow smaller, more uniform trees, which has actually widened the gap between ecological conditions on public and private land. These younger forests will not provide the same type of biological diversity as was traditionally found on nonindustrial private forest lands.

Issues at Stake in the Plan—Still Debated

Tension and debate surrounding society's perspectives on forest management will always be with us. These tensions primarily reflect competing values and worldviews. Each philosophy is based on a set of complex hypotheses, some which the scientific community is only now beginning to imagine how to test. In a sense, the Plan is an elaborate case study that might begin to determine whether these philosophies are truly exclusive, or if they can coexist on the same piece of land at the same time. The Plan attempts to blend these opposing views of natural resource management by using a mix of elements from the fields of conservation biology, silviculture, and ecology.

The Plan is not simply a scientific document, it attempts to address the sociopolitical conditions that made it necessary. It attempts to address questions of economic

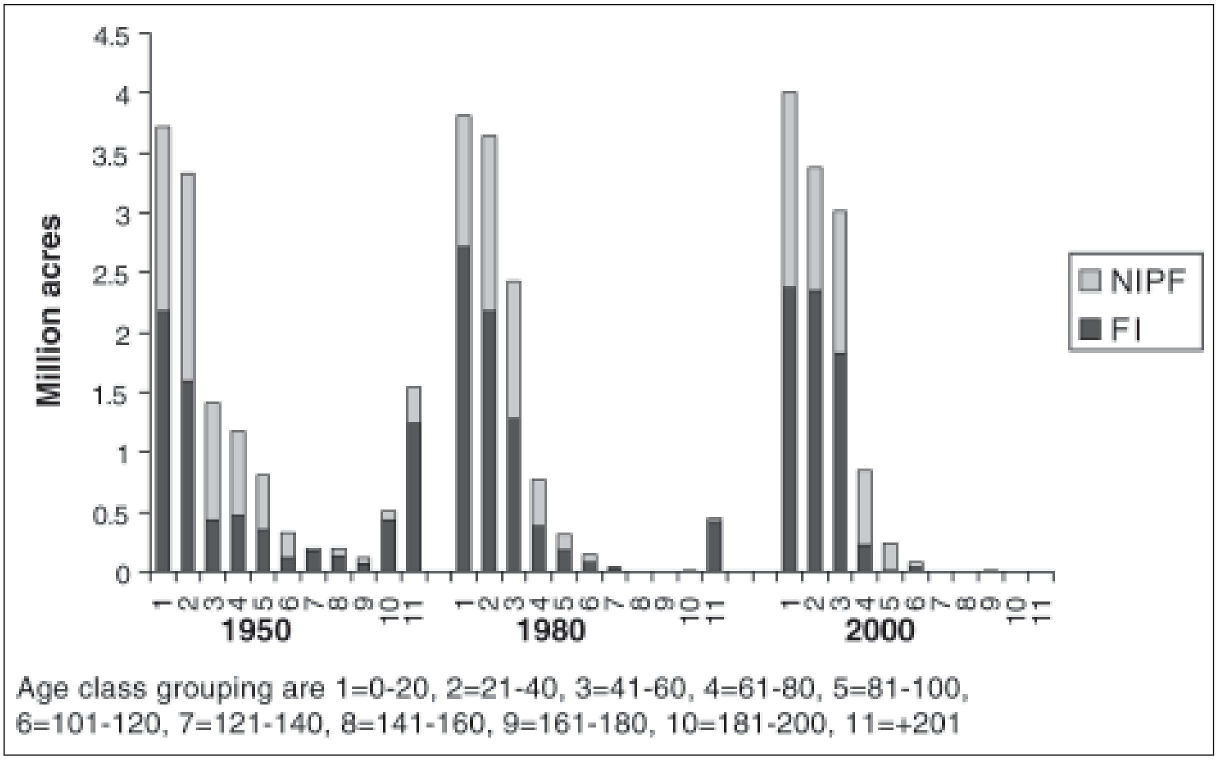

Figure 2-3—Private inventory by age class for the Douglas-fir region (western Oregon and Washington), 1950, 1980, and 2000. FI = forest industry, NIPF = nonindustrial private forest. Source: USDA FS 1963, Haynes 1986, Haynes and others 2003.

Public vs. Private Land: the Challenge of Designing Late-Successional Reserves

Late successional reserves (LSRs) in combination with the other allocations and standards and guidelines are designed to serve as habitat for late-sucessional and old-growth-related species including the northern spotted owl (USDA and USDI 1994). The bifurcation of conditions between public and private forest land complicated Plan design, because part of the political compromise associated with the Plan was that it would only affect federally administered land. This eliminated much of the land with the best potential for spawning and rearing habitat for coho salmon because these low-lying coastal areas are largely in private hands. In general, the desire to protect the remnants of old forest and key watersheds dictated placement of LSRs within the federally controlled landscape. According to Miles Hemstrom who was then the regional ecologist for the Pacific Northwest FS Region and participated in designing the reserves, the process was intended to include the best remaining blocks of old forests, whenever possible, in key watersheds while paying attention to known spotted owl occupation areas. This set of criteria begs the question, strictly from a scientific standpoint, of whether the existing reserve network is the most desirable network even though it was the most pragmatic network given the combination of land ownership and vegetation patterns that existed at the time. This suggests that the current reserve network could, in fact, be inefficient and that some other network could provide the things promised by the Plan by using less space and in less time. But it is important to remember that even though scientists might be able to recommend a more efficient plan, there is currently no political push to do so.

well-being by considering how jobs in timber-dependent communities will be affected and recognizing other cultural issues generated by political decisions associated with the Plan. As a result, it layers the fundamental questions about maintaining ecological processes and biological diversity onto a social question that asks how we might manage public lands to address the environmental, economic, and social equity concerns that shape Americans' everyday lives.

Furthermore, although tension and debate surrounding the competing values of forestry will always be with us, the intense regional conflict that led to the development of the Plan has receded to a more manageable level. Ten years ago the region faced an injunction on timber harvest on federal forest lands, and was mired in legal battles and emotional debates. Out of this came the tremendous efforts of the administration and federal agencies to redirect the regional standoff toward compromise. As Pipkin describes it: "The Northwest Forest Plan was upheld by the courts, the injunctions were lifted, and the region began to move forward again. This was an important accomplishment—from a situation characterized by stalemate, with no end in sight, to one in which progress could be made on ecological, economic, and social fronts." (Pipkin 1998). Ten years later we recognize that conflicts will continue, and there is still room for improvement. However, the Plan, with its common vision for the management of federal lands, can take credit for defusing a volatile situation and creating a more civic atmosphere.

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Chapter 3: Synthesis: Interpreting the Northwest Forest Plan as More Than the Sum of Its Parts

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Introduction

Chapters 5 to 10 interpret the status and trend reports and available science for each of the six major Northwest Forest Plan (Plan) elements (socioeconomic implications; the conservation of old-growth forests; listed and other species; aquatic systems; and adaptive management and regional monitoring). Each element was individually addressed, partly as a way to help understand and explain them, and partly because science is organized by discipline. Here, we consider the elements collectively. We also take the liberty to examine broader contextual factors and look for patterns in available data extending back as far as 50 years. Then we turn our attention to examining possible directions for federal forest management in the next 50 years. We also explore how these perspectives can be integrated with management and policy. Integration starts by recognizing that federal land managers and researchers have very different roles and perspectives. Managers are responsible for developing and applying coherent management strategies to meet complex societal goals, with legal, funding, and personnel constraints, and through public input. Management strategies also seek to integrate various researchers' disciplinary perspectives and be consistent with management experience and knowledge. We seek here to help with this difficult task by revisiting principles of science-based management and by illustrating the debate needed to integrate science and policy, from our perspective as researchers, through specific examples.

Interpreting the Collective Evidence From the Plan's First Decade

Our condensed tabulation of Plan performance (table 3-1) suggests a collection of met and unmet expectations, each depending on individual points of view. People most concerned with ecological conditions may be pleased with many of the changes. People concerned mostly about timber-dependent communities and adaptive management processes will likely be less pleased but may also believe that outcomes could have been much worse. The decline of northern spotted owl (see appendix for scientific names) populations in the southern part of their range was at the low end (2 percent per year) of the wide range of expected decline (0.7 to 8.4 percent per year; chapter 7), but at the high end (7.5 percent) in Washington for reasons not well understood—possibly related to increasing barred owl populations. The decade saw a net increase in older stands that may eventually support more owls. The area of stands that grew into large size classes was greater than losses of older stands from harvesting and fire, even with the 500,000-acre Biscuit Fire. Marbled murrelets appeared to maintain their population, although monitoring is limited to the last 4 years and results may be confounded with changing ocean conditions and a variety of other factors. Multiple interpretations suggested that older and riparian forests did better than expected, a result of harvest lower than expected in the matrix and changes as forests grew into larger size classes. At the time the Plan was written, species habitat models were often seen as a way of determining population trends more efficiently and less expensively than by direct measures. We have learned that building habitat models to predict populations is frequently as complex and difficult as estimating actual populations

Table 3-1—Coalesced key short findings from Plan monitoring (see other chapters for details)

Indicator	10-yr expected[1]	10-yr findings[2]	10-yr deviation	Relevance to the Plan and its implementation
Older forests (FEMAT definition)	Annual increase (1.2%) (reserve lands only)	Annual increase (1.9%) (all land allocations)	Rate of increase higher than expected	The Plan slowed old-forest harvest; implementing nearly stopped it (chapter 6)
Older forest losses from fire	Moderate (2.5%)	Dry provinces (1-9%) Wet provinces (0-1%)	Average over all provinces (1.8%) near expected	Losses were mostly in dry provinces, and fuel reduction was less than planned (chapter 6)
Realized owl populations in northern range	Slight to large decline (0.7-8.4% loss per yr)	Large decline (7.5% loss per yr)	High end of range	Declines may have resulted from habitat loss, barred owls, and other factors (chapter 7)
Realized owl population in southern range	Slight to large decline (0.7-8.4% loss per yr)	Slight to no decline (2.0% loss per yr)	Low end of range	Owl use of brushy habitat appears important (chapter 7)
Plan-wide owl habitat	5% loss to harvest and fire	Slight decline (1.3% loss)	Rate of decline less than half	The Plan slowed habitat loss; gains in older forest do not yet meet habitat standards (chapter 7)
Plan-wide murrelet habitat	Conserve most remaining habitat	Little (2.3%) lost on federal lands	Near expected	The Plan slowed habitat loss and implementing curtailed it further, but other factors are likely involved (chapter 7)
Plan-wide murrelet populations	About a 35% decline	No change in 4 years	Less decline than expected	Ocean conditions and recruitment may explain unexpected stability (chapter 9)
Other older forest species	Maintain with annual review	Many new sites discovered and species protected	Site protection as expected; population trends unknown	Although abandoned in 2004 through a SEIS and new ROD, the Survey and Manage program was reinstated in 2005 by court order following lawsuits brought by environmental groups. A new SEIS is currently in progress that continues the intent to abandon the Survey and Manage program (chapter 8)
Watershed condition scores	Maintain or increase	Of 250 watersheds monitored 60% increased, 39% maintained	As expected	The Plan curtailed most riparian harvest leading to desirable scores (chapter 9)

Table 3-1—Coalesced key short findings from Plan monitoring (see other chapters for details) (continued)

Indicator	10-yr expected	10-yr findings	10-yr deviation	Relevance to the Plan and its implementation
Road decommissioning	Unspecified	10 miles for every mile built	Large ratio; low miles	The Plan generally decommissioned few miles of riparian roads in any given watershed (chapter 9)
Altered riparian boundaries	Many	"Very few"	Fewer than expected	Modifications of boundaries was hindered by reluctance of managers to make decisions during watershed analyses (chapter 9)
Timber production in matrix	8.5 BBF distributed evenly over the decade	<0.5 BBF per yr	Harvest much lower than expected	Implementing ran into various problems, including lawsuits and protests (chapter 5)
Timber production in late-successional reserves	Allow some salvage logging	Thinning in some reserves	More thinning volume than expected	Thinning in late-successional reserves made up for some of lost matrix harvest (chapter 6)
Community stability	Stability	Two thirds changed	Both positive and negative changes	The Plan had less positive or negative influence than expected (chapter 5)
Interagency and agency-citizen collaboration	Improve relations	Interagency, yes; agency-citizen-mixed	Interagency better than expected; agency-citizen less than expected	Interagency collaboration worked well in many, but not all, places (chapter 5)
Adaptive management areas (AMAs)	10 AMAs providing changes to the Plan	Few active AMAs remaining	Much less than expected	As implemented, AMAs were insufficiently flexible or institutionalized (chapter 10)
Adaptive management process	Not well specified	A few projects outside of AMAs	Unknown	The process was not widely integrated into agency missions (chapter 10)
Regional monitoring	Not well specified	Five modules are functioning well	Near expected	Regional monitoring was well institutionalized and funded (chapter 10)
Employees-Forest Service (as capacity indicator)	Slight decline	Large decline (40-60%) in OR NF	More than expected	Plan goals hampered by sharply declining FS workforce (chapter 5, 10)
Employees-BLM	Slight decline	Slight decline	As expected	Capability was continued (chapter 5)
Manager-researcher collaboration	Improved at least on AMAs	Improved relations generally	More than expected	The Plan was more science based than before (chapters 5, 10)

[1] Few well-quantified expectations were included in the Plan. Here, we reconstruct expectations from FEMAT, the Record of Decision, and participant's recollections.
[2] Findings are derived from data in background monitoring reports. Percentages are per decade unless otherwise noted.

The Biscuit Fire in southwest Oregon burned nearly 500,000 acres in 2002.

thus, models may not be good substitutes for population estimates. In general, the Plan can support conservation and restoration of habitat, but wildlife populations may respond to a variety of other factors, only some of which are driven by habitat.

Continuing lawsuits and other expressions of dissatisfaction suggest that desired consensus and trust in management have yet to be fully achieved. Timber production was far less than expected in the matrix allocation; some of this loss was made up by greater than expected production from thinning in plantations in late-successional reserves. Interviews suggested that timber-dependent communities were disappointed in the Plan, but census data suggest that a

Richard Haynes

Stevenson, Washington, is a former timber-dependent community; community action and residents transformed it to meet changing recreation demands.

relatively small number of communities were severely affected. Some job losses were offset by unexpected factors such as a generally good regional economy and new services and development to accommodate inflowing retirees. Pronounced losses of federal jobs were observed, more than 50 percent on some Oregon and Washington national forests (Charnley and others 2006). Losses in Plan-area national forests in northern California were somewhat less, and USDI Bureau of Land Management (BLM) district jobs were relatively stable. Average national forest nonfire budgets in the Plan area dropped about $250 million or 50 percent during the 1990s, driven by reallocation of national funding.

The specific interpretations of these observations reside in the chapters in part II and in the status and trend reports. Of interest here is the general result that some changes were greater than expected and others less. A noticeable range exists in the strength of evidence with which conclusions can be drawn (discussed in chapters 5 through 10). This range is attributable to the nature of available information and how it was evaluated.

Recent scientific developments add to our understanding of Plan assumptions and help to interpret Plan implementation. Key findings from relevant research studies include:

- Areas with diverse early-successional forest will likely decline in the future with current strategies on public and private lands (see chapter 6).
- Diverse pathways of succession lead to older forest condition; a common one has low conifer densities at young ages developing into multiaged stands with closed canopy at old age (see chapter 6).
- Definitions of old growth by scientists and society are changing and diverging (see chapter 6).
- Thinning plantations to move in the direction of older forest habitat appears promising (see chapter 6).
- Successful adaptive management is generally rare in natural-resource management (see chapter 10).
- Active adaptive management at large scales, although rare, is possible with sufficient leadership and collaboration (see chapter 10).
- New approaches to public participation and adaptive management have evolved (see chapter 5).
- The importance of monitoring in facilitating productive dialogue about management possibilities was recognized (see chapter 10).
- Aquatic systems are far more dynamic than has been realized; benefits from some kinds of fire and landslides are newly recognized in some systems (see chapter 9).
- A new, mixed-severity fire regime is recognized; numerous older forests thought to be in high-severity regimes are now in mixed regimes (see chapter 6).
- Federal lands have a small proportion of the best coho salmon and murrelet habitat (see chapter 9).
- Barred owls may be replacing spotted owls, especially in the northern range (see chapter 7).
- Owls in the checkerboard lands in their southern range may have fared well because of adjacent, brushy foraging habitat (see chapter 7).
- Nonfederal lands have important regional effects in contrast to Plan assumptions (see chapter 5).
- The timber industry has adapted to changes, and some of the adaptations benefit regional employment (more manufacturing jobs per volume of wood processed; see chapter 5).
- Communities express different degrees of adaptability (see chapter 5).
- New kinds and magnitudes of complexity and uncertainty are recognized (see chapter 5).

Most notably, ecosystem complexity and dynamics, both social and ecological, are emphasized in many studies. We also see some surprises, such as unanticipated mechanisms associated with changes in owl and fish populations. Some of the unexpected changes—such as new industry and community strategies—appear to be adaptations to the Plan. These findings are discussed in detail in part II chapters. Later, we look across the findings to seek emerging themes that might apply to the Plan as a whole, rather than to individual Plan elements. Before we try to draw many conclusions, we next place these findings in a broader, longer term context.

Interpreting the Evidence in a Broad Context Over the Last 50 Years

Changes, whether induced by the Plan or other factors, are best understood when placed in the context of the large physical, biological, and societal complexity of Pacific Northwest landscapes, and by looking at the changes over timeframes longer than 10 years. Some of the spatial complexities are captured in the maps depicting older forests (Moeur and others 2005, fig. 12) and census data (Charnley and others 2006, fig. 2-5). We graphically examine available data to look for trends in the 40 years leading up to the Plan compared to trends observed in the Plan decade (figs. 3-1 and 3-2). We examine these graphs to see if longer term trends separate themselves from the noise of short-term variability.

National trends and within- and between-state migration in human population are known to drive many factors that influence management direction on federal lands (fig. 3-1a). Increased human presence in the wildland interface has increased demand for water and recreation and has increased the danger and costs of controlling wildfire and hindered reintroduction of low-intensity fire. Because managing federal lands has been ground zero for a societal debate over how these resources and values are collectively met, forestry has been elevated to the national political debate in recent decades. The volatility of social and political change (fig. 3-1b) makes long-term planning a challenge. Examining all of these graphs together, shows some interesting disconnects. For example, U.S. housing starts, although quite volatile, do not increase with U.S. population or decrease with Northwest harvest—no long-term trend is observed over the 50 years of data (fig. 3-1c).

Wood production from federal lands fluctuated moderately from 1960 to 1990, with only a small long-term declining trend (fig. 3-1d). The subsequent steep decline started just before the Dwyer injunction,[1] well before the Plan was implemented. Wood production by forest industry varied with market fluctuation until the late 1970s. Industry harvest declined from then until about the start of the Plan in 1994, and then leveled out during the Plan decade. The stumpage value of harvested Douglas-fir spiked after the Dwyer injunction and then began to decline during the Plan decade, but it remains well above historical prices. A major change occurred in the stumpage-price curves—previously large-diameter logs were worth two to three times more per unit volume than medium-diameter logs. This premium has disappeared, apparently because of increasing demand for small logs being processed in new, efficient mills and loss of mills able to process large logs. Short-term variability in lumber and wood-products jobs (fig. 3-1e) is smaller than variability in harvest or housing starts. Jobs were relatively steady up to 1980 and then began declining. The jobs per unit of harvest actually increased starting in the late 1980s and remains at a 50-year high. Economists think this increase came from increased mill efficiency, the loss of the log-export markets, and the associated increases in local manufacturing (see chapter 5).

The trends in owl populations[2] (fig. 3-2a) and late-successional old-growth forest, both major indicators for gauging progress, are mixed. Owl populations showed both continued declines and stable populations depending on differences in underlying factors and physiographic region. The areas of older forest are stable to expanding, and expectations are for continued increases (see chapters 6 and 7). The decisions not to cut as many older stands in the matrix as the Plan had called for, and to focus more on thinning plantations, yielded a double benefit to late-succession-dependent species—fewer large trees were cut and small-tree growth was accelerated.

Tree harvest (not counting thinning in plantations) was nearly stopped on federal lands during the Plan decade. Although aquatic specialists perceived that watersheds are generally in a poor state, cumulative harvest in riparian zones leveled off to about 5 percent (based on

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[1] 1994. U.S. District Court. Seattle Audubon Society and others v. John L. Evans, Washington Contract Loggers Association and others.

[2] Data from Anthony and others, in press.

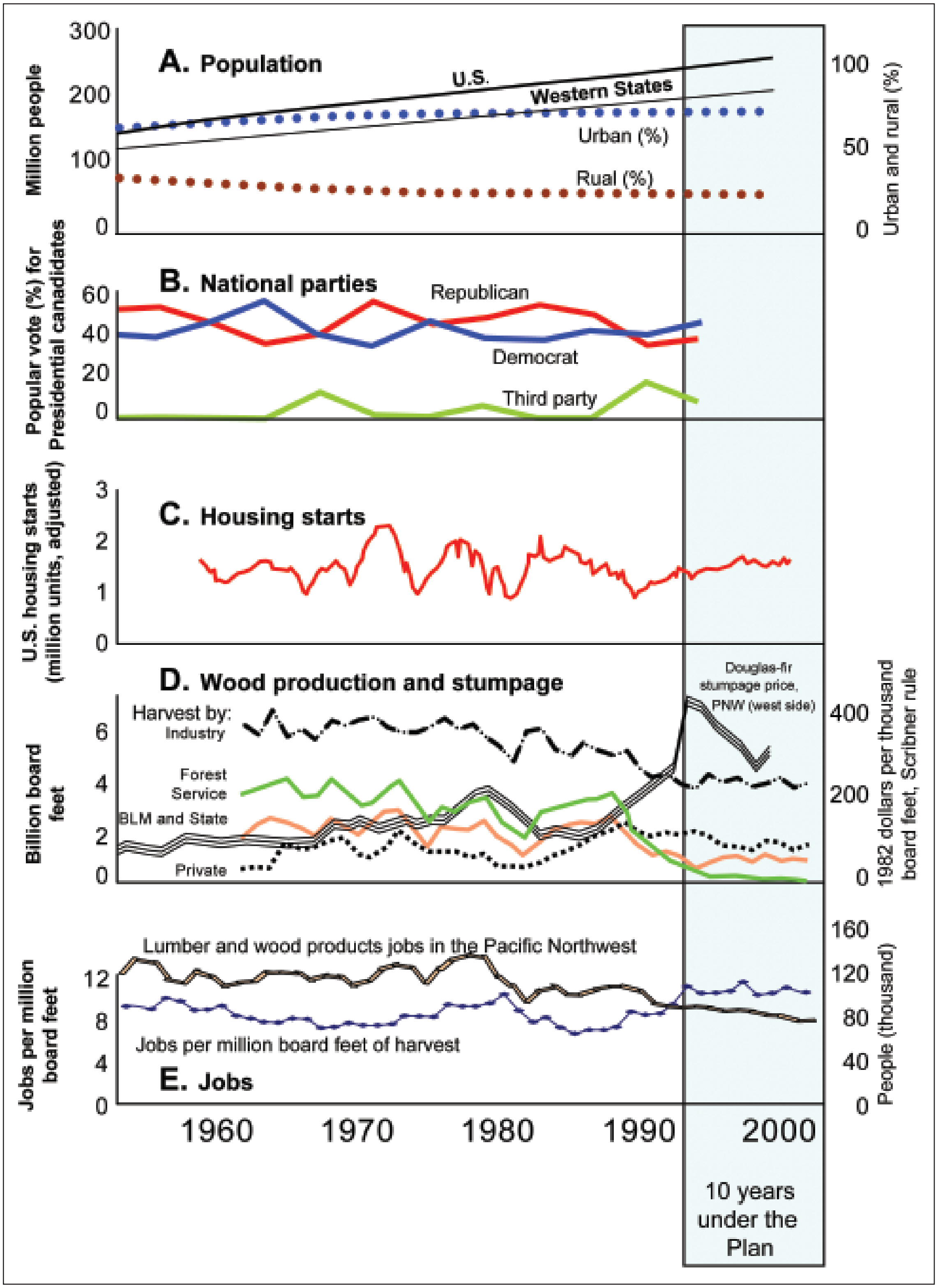

Figure 3-1—Fifty-year variability and change in (a) U.S. population, (b) voting patterns, (c) housing starts, (d) wood production and stumpage price, and (e) forest-sector jobs. Figures a to c are from Caplow and others 2000; d and e are from our chapter 5.

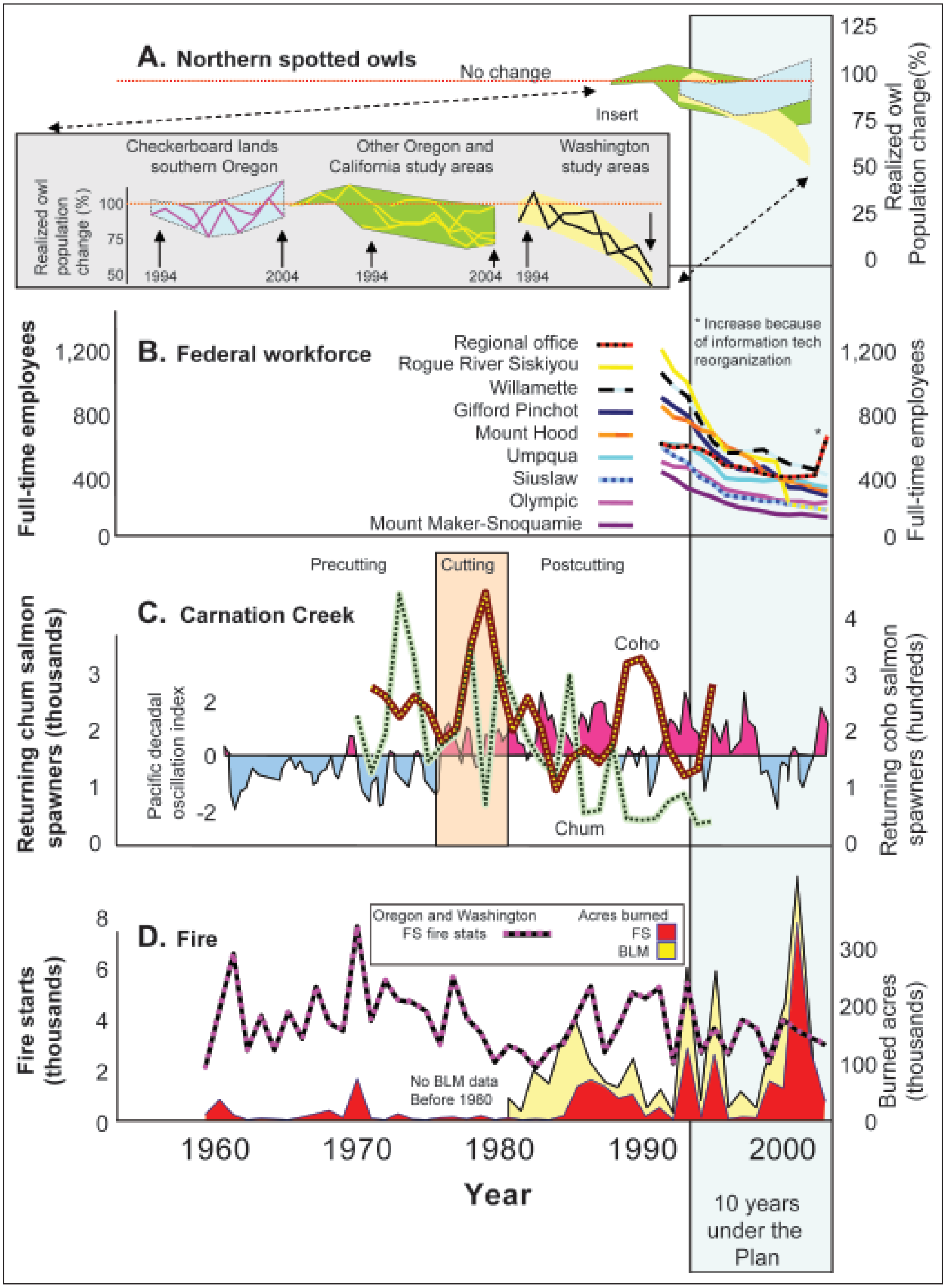

Figure 3-2—Fifty-year variability and change in (a) owl populations (the insert separates population groups; from Anthony and others, in press); (b) management capability expressed as workforce size (FS data); (c) fish populations, tree cutting, and ocean conditions (from Tschaplinski 2000); and (d) wildfire starts and Forest Service (FS) and Bureau of Land Management (BLM) combined burned acres in Oregon and Washington (Forest Service data). Missing data from early years was not collected or was not available.

a sample of 250 watersheds; Gallo and others 2005), and a small number of riparian roads were decommissioned. The quality of aquatic habitat, defined by these factors, therefore improved in the 1990s. Issues arise with a more indepth analysis (see chapter 9). For example, although direct funding for road maintenance has remained fairly steady, lack of surface replacement funds from timber sales resulted in an estimated 70 to 80 percent shortfall in needed resources for basic maintenance.[3] Unfortunately, no long-term data on fish populations are available in the Plan area to verify that habitat and populations are empirically well linked. The closest, most reliable data come from the Carnation Creek study on southern Vancouver Island (fig. 3-2c), where fish were monitored before and after 41 percent of the watershed was harvested. Clearly, returning salmon populations have high short-term variability making trends difficult to discern. As more is learned about controlling mechanisms and their interactions and variability—including ocean conditions—the emerging story is that stressors and populations are highly dynamic so that fluctuations cannot be attributed with much confidence to single causes, such as forest harvesting (Tschaplinski 2000). Extrapolating the Carnation Creek evidence (significant negative correlation of tree harvest to returning chum; little correlation to coho) across entire regions is likely further confounded by the type and extent of harvest, the local geomorphology, and many other factors. Research and monitoring may help us to better understand these assumptions and better anticipate new mechanisms, such as instream food availability, long-term disturbance effects, delayed effects, and factors limiting salmon during population dips. A network of more controlled management experiments, with aggressive treatments and taking perhaps 20 years, is likely needed to substantially improve our understanding to better manage these resources. Many partners will be required and institutional barriers overcome to accomplish this task.

[3] Personal communication. Michael Furniss, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521-6013.


Two young spotted owls.

The federal-land acres in Oregon and Washington that were burned in wildfires increased dramatically in the early 1980s—relative to the 1960s and 1970s—although the number of fire starts appears reasonably steady (fig. 3-2d). The recent increase in wildfire is widely thought to result from fuel accumulation, caused in part by fire exclusion (see chapter 6). A broad look at the wildfire evidence provides insights into the difficulty of associating change with specific management actions. Uncertainties arise from numerous interacting factors, statistical interpretations, and temporal perspectives. For example, the disconnect between starts and area burned is obscured by the interactions of increased fuel, weather, ignitions, and fire-response capacity. Although the average acres burned during the Plan decade increased, compared to the decade before the Plan (1985 to 1994), the confidence intervals around these averages strongly overlap.[4] When the historical record is extended from 1954 back to 1916, new conclusions emerge, such as that recent wildfire acres are actually less than those observed from 1916 to 1945 (fig. 3-3). Looking further back, wildfires in the first 15 years of the 20th century in Oregon and Washington have been reported to be quite low

[4] Rates for the Plan decade are 1.7 times those of the decade before, but the 95 percent confidence intervals strongly overlap (a valid, simple statistical test is not possible because of the likelihood that autocorrelation in the time-series data would increase or decrease the variance estimates). Further, this increase disappears when the 2002 fire year, with the 500,000-acre Biscuit Fire, is not considered.

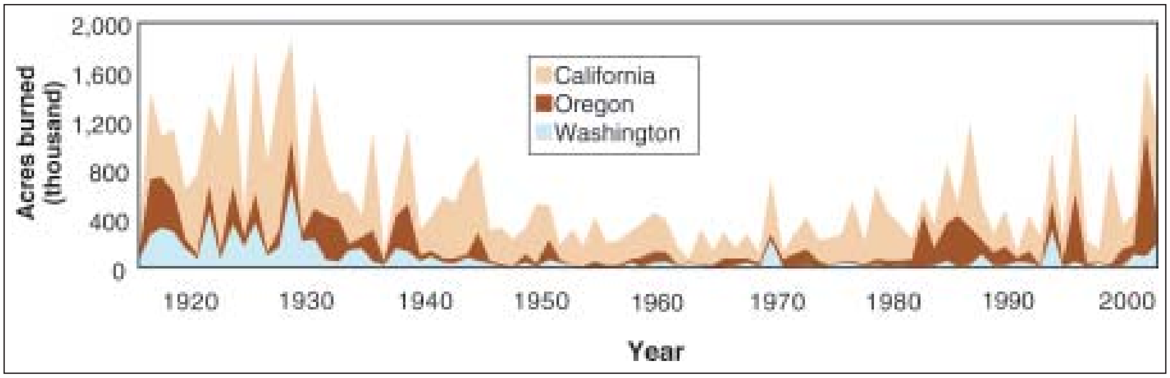

Figure 3-3—Estimates of total acres burned in wildfire on all ownerships from 1916 to the present, divided among Washington, Oregon, and California. Note that California data mostly come from fires outside the Plan area. Data compiled by David L. Peterson, Pacific Wildland Fire Sciences Laboratory, 400 N 34th St., Suite 201, Seattle, WA 98103.

(although the data are less certain), and changes appear related to shifting climate—leading climate modelers to theorize that wildfire is driven substantially by climatic shifts (McKenzie and others 2004). The distribution of wildfires may be shifting as well. Although wildfire rates are close to that expected for the entire Plan area, most of the fires were in the drier provinces (see chapter 6).

The only data we found that reflect the long-term capability of agencies to carry out the complex directives of the Plan were budget and personnel data dating back to 1990 (fig. 3-2b). Reductions in USDA Forest Service (FS) personnel were steep, beginning some time before the Plan started. Numbers of BLM personnel were much more stable. These changes in capacity are likely related to the other changes (Charnley and others 2006) but evidence of direct connections are difficult to find.

Some patterns under institutional control (for example, FS employee numbers) appear to have less short-term variability than market-driven factors like stumpage price. Patterns influenced by the broader economy, such as housing starts, harvest on industrial lands, and wood-products jobs have intermediate variability. Patterns influenced by natural processes, such as fire, ocean condition, and animal populations, appear most variable. People's lack of control over dynamic natural processes will continue to challenge institutions.

Richard Haynes

Timber harvest in the Pacific Northwest declined, but lumber production for domestic markets increased, mitigating employment declines

Patterns in some outcomes clearly rise above the inherent noise of their short-term variability, but few can be cleanly linked to the Plan itself. Looking at these patterns together, eight changes are most notable (table 3-2). Other smaller changes are clear, and perhaps no less important. The perspectives gained from available long-term data on outcomes (effects) suggest that the Plan is but one of many interacting processes (causes) at play. An important lesson from the Plan monitoring is that simply monitoring effects without learning about their causes will not offer much guidance when outcomes turn out to be undesirable.

Table 3-2—Big changes in the last 50 years, descending in magnitude (from variables displayed in figs. 3-1 and 3-2)

Outcome	Observed change	Pattern as related to the Plan
Older forests	Loss of older forest stands in the last 5 years is less than 5% of the late 1980s peak losses.	The decline in loss began 5 years before the record of decision (ROD) was signed.
Wood production	Production in the last 5 years is less than 10% of the late 1980s peak.	Production is shifting to thinning of young stands in reserves.
Wildfire	Acres burned 1950 to 1980 were about 10% of burns 1980 to the present.	Long-term trends and variability obscure direct relation to Plan.
Returning chum salmon, Carnation Creek	Returns in the mid-1990s are about 20% of the mid-1970s returns.	The variability, location, ocean changes, and cutting intensity do not relate well to the Plan.
Capacity, using FS employee numbers	Forests now have 30 to 40% of the permanent employees in 1990.	The decline began at least 5 years before the Plan.
Owl populations in Washington	About 60% of owls are left at present, compared to 1993.	No pre-Plan data are available to make any inference.
Douglas-fir stumpage prices	Prices before 1990 were about 65% of prices during the Plan decade.	Prices appear related to regional timber production.
Regional wood-products jobs, all ownerships	About 70% of jobs remain at present, compared to the peak in 1980.	A steady decline started in 1980 and continues through the Plan decade.

Considering Other Issues and Emerging Perspectives for the Next 50 Years

Our review of regional monitoring and recent research was not intended to be comprehensive or to provide much information about emerging issues. So next, we seek to make monitoring more useful to future management direction by interpreting the results from monitoring and research in a broad context (above) to reveal crosscutting perspectives (below).

Our Evolving Understanding of Science-Based Management

The Plan in the past decade has often been looked upon as a model for large-scale ecosystem management (see Busch and Trexler 2003, Johnson and others 1999, Sexton and others 1999), and it will likely continue to do so. Specifically, the Plan has influenced discussions on the role of science, the role of assessments covering broad geographic areas, sustainability of ecological and social processes, and the need for multijurisdictional and adaptive-management approaches. We hope the experience we are describing in this 10-year interpretive report continues to contribute to the broader debate. In this section, we examine how the experience with the Plan has shaped our understanding of some of the issues surrounding managing complex ecosystems.

Role of federal lands—

Keeping changes on federal land in a holistic ecosystem perspective is important. For example, Oregon published a state-of-the-environment report (Oregon Progress Board 2000), where they concluded that:

> The greatest opportunity for improving Oregon's environment in this generation occurs on lands that Oregonians control: on state, county, and private lands. Much of what potentially can be achieved on federal lands is already reflected in new policies and plans for managing forest and range lands. Private lands have become increasingly important to solving many of Oregon's environmental problems for this generation.

Placing the federal lands in context with private timberlands in meeting Plan intentions is also important. The impression that federal lands can solve the significant issues that led to the Plan is false. Federal lands are only part of the solution toward achieving broad societal goals such as conserving biodiversity, maintaining forest productivity, or maintaining and enhancing socioeconomic benefits to meet societal needs (table 3-3). New cooperative relations between federal and other landowners might be expected in the future.

Many people believe that Oregon, Washington, and northern California have a better state of the environment than many other states or countries around the world. Thus, one interpretation is that the federal lands in the Pacific Northwest represent the best of the best. "Saving the best" is a legitimate approach, albeit perhaps with different consequences than "fixing the worst."

Complexities of multiple scales—

The evidence from monitoring and research affirms that ecosystems are changing in complex ways and are rarely constant in time or space. The area covered by the Plan—established to follow the range of the northern spotted owl—includes 12 distinct provinces classified by their differences in climate, vegetation, geology, and landforms. Designers of the Plan recognized this variability and included options for modifying standards and guidelines even as they attempted to develop regional direction for the sake of efficiency. One of the Plan's biggest challenges was and is how to implement a regional vision, one local project at a time. Several issues deserve discussion.

Midscale transitions—

In reviewing the Plan's first decade, we have observed some potential gaps in the spatial scale of planning and activities. For example, many acres were thinned to meet regional needs such as owl habitat, fuel reduction, and timber production, but how much landscape thinking went into those activities is not clear. Many ecological and social processes are only important at the middle scales of provinces, larger watersheds, and diverse landscapes; for example, in dry provinces, meeting owl habitat needs and reducing the risk of high-severity fire. Midscale analyses are intended to help make the transition between scales, by being more spatially explicit and more site specific than regional plans. Midscale analyses could also play a role in defining monitoring needs at this scale, helping to develop a hierarchy of information. The opportunity exists to make the next round of forest and resource unit plans facilitate both management and monitoring activities across this hierarchy.

Site specificity—

Substantial knowledge of local conditions and the flexibility to respond to this understanding are not optional in multiscale management. Regional standards and guidelines—for example, 10 down logs per acre—enforced everywhere fail to take advantage of the critical knowledge of local agency specialists. Local adjustment processes (for example, to change riparian buffers and to allow active adaptive management) had mixed success for a variety of reasons. Site specificity is not possible without such processes. The concept of site specificity is highly developed in silvicultural research and practice. For example, Hawley (1921), when discussing the reasons so little was known about silviculture, noted that "... silvicultural practice is

Table 3-3—How older forests, habitat, and timber harvest are distributed between public and private lands as a percentage of area over the Plan area

Ownership	Older forests	High-quality owl habitat	High-quality murrelet nesting habitat	Timber harvest
		Percentage		
Federal and state	77	59	50	15
Private	23	41	50	85

Note: see chapters 5 through 7. Data represent 2000-2005

essentially a local consideration, varying in important details from forest to forest." This observation remains true today. Scientific inference to complex goals across complex terrain remains limited. For example, research ecologists often develop general hypotheses and can rarely test them in many locations, and research silviculturists have a tradition of testing hypotheses in locally unreplicated blocks, often on accessible, gentle terrain. Only the local agency specialists can think about how well these ideas will work in specific sites. Multiscale managing could come to terms with this disconnect. We are concerned that sharp reductions in field personnel may limit understanding of site specificity and hence the successful merging of general principles with local knowledge.

Challenges of managing complex systems with simple rules—

One of the biggest challenges of ecosystem management is the complexity of its application. The uncertainties arising from multiple dynamic processes playing out over an initially variable landscape are large, and they cannot be easily dealt with by overly simplistic strategies developed to be efficiently applied. The concepts of land-use designation, boundaries, and best practice are involved.

Bruce Marcot

Although heart rot fungus is not desirable in trees grown for timber, it can create hollow standing trees and down logs, which are important habitats for many species of wildlife including swifts, pileated woodpeckers, fishers, raccoons, bobcats, coyotes, and black bears.

Dynamic forests and fixed management boundaries—When the FEMAT options were developed, scientists knew that the landscapes of the Pacific Northwest were dynamic at all scales. Incorporating this dynamism into a 100-year plan with mapped land-use designations was a major challenge. Many old-growth forests in the region required centuries without high-severity fire to develop, and others required low-severity fire every 20 years or so. Although fixed land-use designations—reserves and matrix—formed the basis of the Plan, the hypothesis was that Plan goals could be met despite the disturbance and succession that would alter the structure and composition of the forests in those designations. The Plan anticipated that silvicultural activities were needed in many of the biodiversity-oriented reserves (80 percent of the federal lands), as well as the timber-production-oriented matrix lands (20 percent of the federal lands). The chosen boundaries were strongly influenced by the patterns of existing older forest, but also by a vision of a future, altered distribution of forest conditions, designed to better meet Plan goals. This reserve-matrix strategy has not been tried before at this scale; thus, the long-term success is by no means assured. Continuing to evaluate the strategy, as well as reasonable alternatives to it, would be wise. Based on only one decade of evidence from monitoring and other sources, we cannot say whether a different spatial arrangement of reserves and matrix would have been more or less effective. We also cannot say with confidence, at this point, whether another management option—such as FEMAT option 1 or 5—would have produced a different outcome. Given the large Plan area, and slow changes in forest conditions, alternatives that may result in different outcomes at 100 years may appear relatively similar in the early decades.

Midscale assessment of the consequences of the current pattern of reserves and matrix allocations—where changes to boundaries or activities in designations were considered—was rare while the Plan was being implemented. Given the threats from high-severity fire, insects, disease, and uncertainties about reaching desired outcomes in the dry provinces, we see reasons to reexamine the mid-scale designations in these provinces, not only from the standpoint of boundaries, but also from the perspective of the kind and intensity of active management needed in all land-use designations to better reach the goals of the Plan. This debate includes the boundaries of adaptive management areas. Should these boundaries change in response to their effectiveness or changing ecological or social conditions? The areas were chosen for a variety of reasons, not strongly considering regional and local institutional capabilities or how well they represented broader areas (Stankey and others 2003a). Some of the more successful adaptive management projects happened outside of the adaptive management areas (chapter 10).

With few differences between how reserves, matrix, and adaptive management areas were implemented, whether land-use designation makes sense seems to be an appropriate question. Perhaps a strategy that just sets goals for protecting old forest and providing some commodity production for local communities, without drawing lines on a map, would have been equally effective—assuming that society could grant this much flexibility to federal agencies.

Challenges of managing under high uncertainty—When all of the evidence is examined, several questions come to light: How well do we know and can we know these systems? How well can we attribute the various outcomes to the Plan itself or, for that matter, to the Plan's implementation? How can planning and managing respond to large uncertainties?

Across all perspectives, evidence of uncertainties and their effects is considerable:

- Spatial variability in the Plan area is known to be large, driven by variation in geology, climate, biota, elevation, and disturbance history (see Moeur and others 2005 fig. 11), which is why physiographic provinces were created by the Plan.
- Monitoring and other evidence exposed large year-to-year variation in owl and salmon population estimates, wildfire acres, stumpage prices, and ocean conditions.

- Some outcomes were surprises, such as owl population shifts, a 500,000-acre wildfire, various lawsuits, changes in the stumpage price, loss of the export markets and industrial infrastructure, community adaptations, retiree relocations, and major FS employee and funding reductions.
- New mechanisms were hypothesized in various chapters, including effects of barred owls and wood rats on spotted owls, different watershed dynamics in larger watersheds, and ecological importance of disturbances and native, early-successional pioneers.
- More complexities were recognized, such as large local variation in fire history, and the need to treat mixed-severity regimes differently.
- Unforeseen future trends also came to light, such as long-term changes in seral-stage distributions, not recognized before (chapter 6).
- Improvements in habitat models were not sufficient to substitute for direct monitoring of population changes.
- The effects of climate change on species and ecosystems in the next decades are potentially large, but also uncertain.

The conclusion that uncertainties are high is supported by recent developments in ecology. Ecologists are increasingly stressing the uncertainty associated with ecosystems and their dynamics (Hubbell 2001, Lande 1991, Lemons 1996, Ludwig and others 1993, Shaffer 2000). As a consequence, both scientists and managers have to contend with uncertainty more than ever and, perhaps, more than they would like. Implications extend to the Plan (Bormann and Kiester 2004).

Clearly, both FEMAT (1993) and the Plan authors recognized high uncertainty in the assessments themselves by invoking adaptive management, adaptive management areas, monitoring, and riparian adjustments as ways to change course as more was learned. Implementing this strategy to respond to uncertainty, however, showed mixed results (chapter 10). Thus, reflections on the magnitude of uncertainties and how to implement strategies to respond to them are both needed. This debate is not limited to forestry. For example, the business management literature uses a term "environmental uncertainty" (extent of unpredictable changes in the external environment, Buchko 1994). A major debate continues on the need for changes in strategy and planning when companies face high uncertainty, such as shifting international trade and manufacturing patterns (Galbraith and Kazanjian 1986). The theory states that decisionmakers operating in highly uncertain environments will adopt a planning process consisting of comprehensive data collection, systematic data evaluation, and decision-making based on analytic outcomes, and managers operating in predictable environments are more likely to rely on experience (Dean and Sharfman 1996). Forest management under the Plan is clearly based on substantially uncertain ecological and social processes; thus, new approaches to planning may be needed to better adapt to changes. The business model suggests that planning could be better based in adaptive management, monitoring, and evaluation closely linked to decisions. Agencies appear to be starting down this path.

In this uncertain environment that Plan implementers are managing in, how they respond to uncertainty is more important than how much uncertainty exists. We offer two strategies to consider: improved, systematic adaptive management and monitoring; and diversified practice.

Systematic adaptive management—
In many attempts under different conditions, adaptive management often is disappointing (Walters 1997). The Plan efforts are largely no different (chapter 10). The institutionalizing of regional monitoring and this mandated, 10-year report does, however, represent major steps forward. Adaptive management was viewed as a cornerstone of the Plan, largely as a mechanism to deal with recognized uncertainties. No alternative to moving forward with developing and implementing an improved adaptive management and monitoring system has emerged. A systematic and fully institutionalized approach could make Plan implementation more dynamic by increasing the rate of learning

through a balance of regional monitoring and management experiments on or off the adaptive management areas (fig. 3-4). A systematic approach could be driven by a small set of corporate questions, geared to focus learning activities, and periodic interpretive steps to integrate disparate knowledge sources in broader and longer term perspectives. Monitoring, management experiments, and periodic interpretation steps would be driven by forward-looking questions because of the time needed to detect changes in complex forest systems. Annual interpretative workshops could help institutionalize adaptive management and respond to the dynamic nature of our understanding by considering changes in approaches to better meet longer term learning objectives. The path is clear to move from opinion-based toward evidence-based interpretation of the vital questions about federal forest lands. We can be optimistic, with strong leadership and a professional focus, that adaptive management can be implemented to bring together managers, regulators, researchers, field specialists, and multiple constituencies in a dialogue more constructive than the current debate. Adaptive management and associated monitoring can be refocused on preparing for future interpretive reports by refining the questions future managers may face.

Diversified practice—
A concept not well appreciated in early versions of ecosystem management is diversifying approaches to spread risks. The concept of diversified practice in response to high risk and uncertainty is simple on the surface: just do not put all your eggs in one basket. Why diversifying is important and how to apply it are much less clear. Putting all eggs in one basket is a risk especially where outcomes are fraught with surprises. Diversified investment portfolios also help illustrate the problem—successful portfolios spread the risk of failure across fundamentally different investments (such as stocks, bonds, and real estate), so that if one type of investment fails another is not likely to follow, thus evening out large fluctuations. Similarly, risk is lessened in forest management when multiple valid

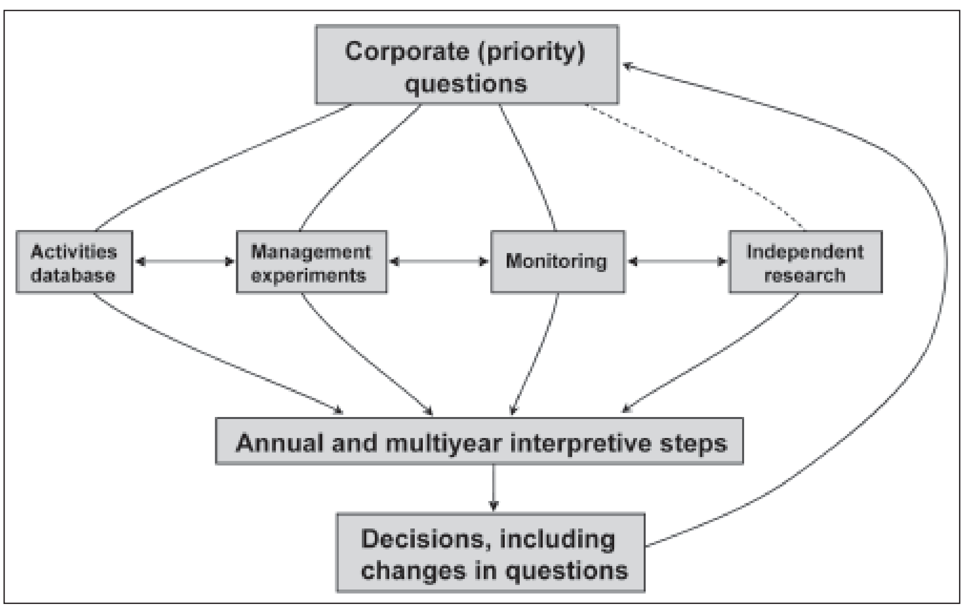

Figure 3-4—A conceptual model for more systematic learning, where corporate questions drive various learning activities that feed into interpretive steps facilitating decisions on whether course changes are needed, as well as on whether to revise the questions.

Best Practice Versus Diversified Practice

Best practice and diversified practice in some ways are genuinely contradictory. A best practice is typically defined when researchers and managers agree on the effects various practices will have on the ecosystem and can choose the single practice ranked best. This choice does not mean that the practice will prove to be the best—after all, taking logs out of streams was once a best practice, as is putting them back now. Diversified practice makes sense either when consensus cannot be reached or when scientists agree that the existing evidence is insufficient to distinguish between alternative hypotheses with confidence. Under these circumstances, ranking practices does not make sense, and in the spirit of not putting all of your eggs in one basket, managers can logically decide to take multiple approaches. When uncertainty is high, diversified practice follows from, and is consistent with, the well-known scientific method of multiple working hypotheses (Chamberlain 1897).

An example: How could forests and salmon habitat be managed to sustain salmon populations? Our understanding of the mechanisms by which forest stream habitat condition affects numbers of salmon is not well developed. We know watersheds vary in important ways and that many factors affect population numbers. We can certainly say that salmon spawning and rearing habitat is necessary, but not sufficient, for salmon populations. Beyond that, more quantitative relations have proved elusive. Is this a failure of the scientists to solve a research problem? No, the problem is simply too complex and too variable to admit easy answers. Does this mean that the appropriate philosophy of science here is the method of multiple working hypotheses? Probably so. These, then, are issues in the conduct of science that may also be relevant input for managers.

approaches to achieving an objective are simultaneously applied. Risk tolerance can be expressed by allocating space to various approaches, which in turn affects the magnitude of the gains and losses. Diversification does not mean adding new objectives in a land-use designation to be achieved by a wide variety of approaches, nor does it insist that widely unacceptable approaches be included. It simply means that the uncertainties are often high enough to warrant trying multiple creative approaches at the same time in the same land-use designation. The Plan did not prohibit such variability, and the Plan also did not encourage it. Clearly, this new paradigm will need to overcome best-practice inertia, and will need to be clearly articulated to regulatory agencies and the courts.

Importance of planning language—

During the 1990s, we have seen concepts and associated terms developed by scientists used generically in societal debates about natural resource management. What scientists often thought to be technical issues became determinants of public opinions. As all concepts mature, many definitions gain clarity; some remain ambiguous by design; and some appear misleading. Herman Daly speaks about the roles of vagueness and clarity in language (Daly 1996):

> While not vacuous by any means, the [World Bank] definition [of sustainable development] was sufficiently vague to allow for a broad consensus. Probably that was a good political strategy at the time—a consensus on a vague concept was better than a disagreement over a sharply defined one. By 1995, however, this initial vagueness is no longer a basis for consensus, but a breeding ground for disagreement. Acceptance of a largely undefined term sets the stage for a situation where whoever can pin his or her definition to the term will automatically win a large political battle for influence over our future.

One lesson from the Northwest Forest Plan is the importance of communicating clearly and frequently.

Here, we examine how some terms have matured and how they may affect the future of the Plan.

"Old growth" is no longer just a forestry or ecological phrase—it has grown into a highly value-laden phrase (Helms 2004, Spies 2004). Some of the more recent uses—forests that lack a history of management and forests with trees older or larger than trees found in plantations—now have little scientific basis. At the same time, forest ecology has advanced to recognize the complexity and variability in all forests, including old growth (see chapter 6). The older forest monitoring module (Moeur and others 2005) accommodated multiple perspectives by analyzing a range of potential definitions. This step is important in facilitating a more informed and connected debate.

Management objectives have sometimes included ambiguous terms to describe intent and rationale. We have seen this practice backfire during the first decade of the Plan. "Forest health" was cited as the major need in many environmental impact statements (EISs) implementing the Plan on matrix lands, rather than timber production (for example, on the Eagle Creek EIS in 1996 on the Mount Hood National Forest; Franklin and others 2001). Forest health, to agency silviculturists, meant thinning to reduce insects and disease, perhaps reduce fuel load, and to promote growth of residual trees; it meant natural progression toward older forest to some people; and others thought a healthy forest was one without human intervention. The lesson, however, is that using "restoring forest health" as a cover for Plan-directed timber harvest in the matrix is not acceptable to the public. We suggest that simple direct language will also help us to write better, shorter National Environmental Policy Act (NEPA) documents that clearly explain proposed direction by connecting rationale and evidence to decisions.

The phrase "adaptive management" was used extensively in the Plan with varying perceptions of success, including some critical reviews in the scientific literature including titles like, *Adaptive Management and the Northwest Forest Plan: Rhetoric and Reality* (Stankey and others 2003a). Much of this variation arose from the lack of effort to forge a common definition or understanding of the concept. That monitoring and adaptive management were considered separate activities initially points to conceptual confusion as well. We sought to more clearly portray a vision in the adaptive management and monitoring (chapter 10). More work is ahead.

The term "reserve" was chosen in the Plan to describe late-successional and riparian land uses that included some active management. Confusion arose from at least two sources. Reserve was not used to describe the matrix allocation or the adaptive management areas where even more-active management was planned. Reserve also sounds a lot like preserve, often used in association with wilderness and park lands. The term has a long and varied history and is now defined by international consensus to encompass both active and passive management (see chapter 6). Changing to a name without a double meaning would not be sufficient without the effort to clearly define and widely articulate what the land-use objectives are.

Lastly, we would like to clear up what is meant by the "Plan." To the public, much of what we describe sounds like a single overarching document that sets the context (and direction) for managing federal forest lands. But land management planners taking a NEPA-centric approach argue that no single plan exists; rather, it is a document that amended 24 forest and district plans.[5] This view suggests that we take care in how we represent future planning efforts if we want to avoid conflict with broader public perceptions.

Issues of trust—

The implementation of the Plan has been slowed by a lack of trust between various citizen groups and land managers. Mistrust arises from questioned intentions, lack of clarity, unwarranted certainty in the debate, and differences between promises made and promises kept. Other forms of mistrust are more rooted in beliefs and social discord. People often have difficulty accepting the intent, objectives, or approaches presented by polar groups. Some of the adaptive management areas were able to assemble diverse stakeholder groups and, through personal interaction, come to consensus on controversial projects that were then opposed by national organizations (Stankey and others 2003b). Trust has a difficult scaling dimension—trust is or is not given at multiple, sometimes independent scales.

Key in this next decade is attending to the factors and processes that can enhance trust between and among people and organizations (Stankey and others 2003b). In the science community, we need to avoid presuming that trust is equivalent to high statistical confidence and association. On the management side, consider how trust can contribute to developing and implementing land management plans, to helping groups (networks) form, to engaging them in the process—including assistance in defining the range of acceptable options and the basis of compromise—and to developing public understanding and support. This last aspect is critical because, as Stankey and others (2003c) have argued, without public understanding and support, the political legitimacy and capacity of management agencies to act effectively is in doubt.

Timber harvest protesters.

Uncertainties about ecological and social processes and institutional capacities could be articulated more openly and clearly than they have been in the past—in planning and decision documents—to manage expectations; a range of outcomes rather than a single outcome would often be more in line with what is known. Convincing people that managing ecosystems for complex resource objectives has considerable uncertainty should not be difficult; after all, if a plan—as ambitious and complex as this Plan is—has never been implemented before, why should people expect great certainty in whether it will or will not work well? Building institutional capacity focused on learning that connects to multiple constituencies may be an important way to build trust. This trust building appears to be happening in the Five Rivers project on the Siuslaw National Forest. After a 12,000-acre management experiment contrasting ways to manage plantations to achieve late-successional and riparian objectives was enjoined, along with many other projects in coastal forests in 1997, the environmentalist plaintiffs, after learning of the project,

[5] Personal communication with senior managers group (informal interagency committee).

asked the court to remove it from the injunction, and the court agreed—even though substantial commercial timber volume was to be sold. Forest industry interests have also enthusiastically supported the project even though it includes significant areas where thinning will not be allowed. Whether such trust-building can happen at larger scales remains unclear.

Bringing Science and Management Together

Integrated management strategies—
Any interpretation of monitoring results and new science cannot be applied without some concept of potential future directions managers might take. The role of science is to inform decisions about those directions. Here are several examples of possible future direction, mainly to illustrate how science and policy may be integrated. But first we need to recognize again that science is only one factor influencing decisions about how to manage federal land. Many people think the Plan is about saving old growth while maintaining lower timber harvests. A careful reading of the original list of the President's principles suggests a more complex set of goals, including economic, ecological, legal, intergenerational, organizational, and perhaps even emotional elements:

- Never forget the human and the economic dimensions.
- Protect the long-term health of our forests, our wildlife, and our waterways.
- Be scientifically sound, ecologically credible, and legally responsible.
- Produce a predictable and sustainable level of timber sales and nontimber resources.
- Make the federal government work together and work for you.

National forests and BLM districts are expected to provide recreation, aesthetic landscapes, hunting and fishing opportunities, firewood, wilderness, special forest products, and many other values not addressed explicitly in the Plan but specified in forest and district plans. Legally, the Plan is an amendment to these plans that deals with a limited range of societal objectives thought to be met only through regional oversight.

Managers understand that scientific information is rarely well integrated in support of their complex management objectives. Fragmented knowledge coming from different disciplines may lead to artificially fragmented approaches, each geared to a specific problem. Managers of federal lands respond to meet multiple public values, but values cannot be efficiently addressed one at a time. Management efficiencies can be found when multiple values can be met together—although not necessarily at the same time or place—which is easier said than done.

In effect, managing federal forests can be thought of as a strategy of strategies, seeking to meet a blend of societal objectives by applying the broad scientific understanding of how to achieve those objectives combined with local on-the-ground experience and knowledge, and within institutional capacities and constraints. Flexibility is the key because all of these factors change through time. The chapters on policy context, socioeconomics, and adaptive management touch on some of the complexities and uncertainties other than those associated with scientific understanding of forest ecology. The dynamics of these social processes have strong similarities with the dynamics of ecological processes discussed in the older forest, species, and aquatic chapters. The full appreciation for the difficulty of the job is understood when the interactions of all of the social and ecological processes are combined.

Examples of integrated approaches—
We develop and discuss a range of potential approaches to pressing issues, to think about how science and policy might be better integrated. These approaches are necessarily vague and incomplete; our discussions are not a scientific assessment of them. The scenarios simply provide a way to think about the integrative problems managers face. The discussion represents the kind of debate that will likely lead to wise policy.

Salvage logging in late-successional reserves—
Salvage logging in late-successional reserves—a contentious issue in implementing the Plan—is a good example of the complexities of the science-policy interface, and the limits to which science can guide management. The Plan allowed for "some" removal of dead trees from late-successional reserves to meet additional non-ecological objectives (USDA and USDI 1994):

> Salvage guidelines are intended to prevent negative effects on late-successional habitat, while permitting **some** commercial wood volume removal. In some cases, salvage operations may actually facilitate habitat recovery. For example, excessive amounts of coarse woody debris may interfere with stand regeneration activities following some disturbances. In other cases, salvage may help reduce the risk of future stand-replacing disturbances. While priority should be given to salvage in areas where it will have a positive effect on late-successional forest habitat, salvage operations should not diminish habitat suitability now or in the future.

With our current state of knowledge, ecological science cannot help much in determining what "some" means and in determining at what rate or extent salvage removal would diminish habitat suitability (see chapter 6). For example, although we know that large dead trees have many ecological functions in postwildfire stands (Lindenmayer and others 2004), we cannot predict how species composition and ecosystem function will change over the long run when only some of the commercially valuable dead trees are removed, leaving various amounts of snags and downed wood. Furthermore, only managers can decide how to weigh the tradeoffs between the uncertain ecological effects and known economic benefits of commodity production from salvage logging. The issue is further complicated by the fact that timber receipts from salvage logging FS land can be used for other fire recovery efforts, such as planting, replacing culverts, restoring trails, reducing fuels, and monitoring. A guiding principle of the Plan was to provide for legally sufficient protection for species and ecosystems and, having done that, to provide for economic and social well-being. This tradeoff was well specified in the record of decision by designating reserves and matrix. Only a few situations remained where managers had some options for additional weighing of ecological and economic values—salvage logging in late-successional reserves is one of them. The pro- and anti-salvage arguments—articulated by different groups of researchers after the Biscuit Fire (for example, Lindenmayer et al. 2004, Sessions and others n.d.)—reflect the scientific uncertainty, multiple interpretations of Plan nuance, and disjointed societal mandates.

We see opportunities for incorporating more science into these decisions, nonetheless. We start by suggesting that learning about postfire management on late-successional and riparian reserves is important, given the uncertainties in how systems will respond to salvage over the long term. Risk of serious flaws in thinking suggests that rigorous comparisons be made between areas not salvage logged, allowing natural processes to unfold; areas with some salvage logging, attempting to speed older-forest recovery and pay for associated actions; and areas with innovative strategies, for example, prescriptions for frequent underburning. Large fires present an opportunity where, by applying active adaptive management (chapter 10), enough initially similar lands can be found for replicating these comparisons. We also see many important research needs, to retrospectively reassess responses of forested landscapes to past fire and salvaging, to explore the effects of disturbance on long-term productivity and biodiversity, and to study poorly understood patterns and processes like the long-term roles of wood and pioneering and invasive plants.

Managing fire-prone forests—
The older-forest and species chapters present a rationale for substantially increasing and repeating fuel treatments over large areas in the drier parts of the Plan area, as a way to maintain important habitat. A new fire regime (mixed

severity) has been identified, and studies have shown that fire histories are more related to local terrain, vegetation, and climate than thought before. The Plan carries mixed messages about how to set priorities among fuel reductions on one hand and maintain owl habitat and avoid Endangered Species Act (ESA)-defined losses (take) on the other, and different scientists emphasize different messages. An active scientific debate is ongoing about the best ways to reduce the spread of severe fire over diverse landscapes. Managers are left with multiple understandings from science, multiple interpretations of Plan language, and not much on-the-ground experience in applying frequent low-intensity fire in these forests. They are also left with the reality that funds to reduce fuels are lacking and court rulings are unpredictable. And they are presented with national priorities to reduce dangers to local communities, as well as to meet other regional and local priorities. Again, the decisions managers make are only partly based on science. The feasibility of managing fire-prone national forest land lies, in part, in whether revenues can be generated in thinning sales to pay for uneconomic thinning, mulching, underburning, planting, and other needs. A major challenge in learning how to reintroduce frequent, low-intensity fire also exists, as does finding alternatives in areas where smoke violates the Clean Air Act. Potentially disconnected needs also require attention, such as maintaining roads and access for economic fuel reduction and for fighting future fire—and decommissioning roads to improve riparian habitat.

We see opportunities to reinvigorate multiscale analysis and management to approach this problem. Multiple interacting objectives are involved, such as protecting life and property, facilitating control of future fires, maintaining suitable habitat for owls and other species, facilitating recreation and hunting, increasing local employment, improving aesthetics, supplying firewood, and many other multiple-use objectives detailed in the local forest or district plans. Multiple interacting patterns and processes are also involved, such as current vegetation; variance in fire regimes; distributions of habitats, populations, and roads; places where backfires might be set; other disturbances; and invasive plants, to mention a few. Each of these objectives and factors scale differently. Multiscale analysis could be developed to examine tradeoffs across the full multidimensional objective-process space. Midscale analyses are central because most tradeoffs are between the regional and local scale. Midscale analyses are intended to help make the transition between scales by specifying approaches for sites to best meet broad-area objectives. Results from regional assessments could be incorporated into midscale analyses to provide context and identify possible issues at this scale. With midscale analyses in the dry areas where the risks to maintaining the ecological functions of reserves is high, considering how the Plan land allocations might be modified to better deal with these highly dynamic landscapes may be necessary. Such modifications need to be considered in light of landscape management strategies and deviations from expected Plan outcomes.

New approaches to managing fire-prone forests could better accommodate the uncertainties identified. For example, in dry forests near towns where fuel reduction is a priority, a range of fuel reduction methods might be tried. Because these communities have real concerns for their safety, they may be more willing to get engaged in a management experiment to rigorously compare alternate methods that they can help to develop and implement. They may also oppose lack of action as one of the methods compared. Management experiments that only include alternative fuel-reduction methods, without a no-action method, will produce valuable information nevertheless. Fuel reduction trials would be a great place to involve the regulatory agencies as full partner in the design and monitoring.

Managing for a distribution of seral stages—
The Plan was created to solve the problem of declining old growth, with the underlying issues of owls and biodiversity in general. Recent projections suggest that, by 2050, older

forests will occupy 75 percent of federal lands in the Plan area, up from 45 percent today (Mills and Zhou 2003). The consequences of a widening gap in ecological condition are poorly understood. Natural disturbance regimes have been used to justify policies seeking to increase older forest on the landscape. Yet those same studies also indicate that landscapes in the Plan area were not completely blanketed by older forest (Nonaka and Spies 2005); in fact, many areas were a complex of young and old forests, with the mixture varying across multiple spatial and temporal scales. As research on the owl in the southern part of its range suggests (Franklin and others 2000), landscapes with a blend of old and diverse early-successional forest may be better for native biodiversity than landscapes dominated by only older forests. Although private and industrial lands will likely continue to have a preponderance of young, managed plantations, diverse early-successional communities may become underrepresented. Vegetation management is very effective at shortening the time and space for pioneers, whereas natural succession often has a prolonged period when pioneer plants and their associates dominate. Many of these pioneer plants are known to control important processes affecting long-term soil productivity and biodiversity.

If a diversity of successional stages at broad spatial scales is desirable for maintaining native biological diversity, then the question becomes: Does the Plan provide for that diversity? Of course, natural disturbances, such as fire and insect outbreaks, will create diverse early-successional conditions in the Plan area. In the moist provinces and to some degree in the dry provinces, however, most high-severity fires will be suppressed, and the amount of diverse younger forests may not achieve what would have been expected under a natural disturbance regime. Consequently, creating some of this diversity in early-successional forest through active management might be desirable. The Blue River study (Cissel and others 1999) is an example of an alternative to meeting the goals of the Plan where active management was used to create a specified distribution and spatial pattern of successional stages across a federal landscape (this approach was actually intended to maintain mature-aged forest conditions and avoid a federal landscape with only young and old-growth stages). The state of Oregon is also trying to implement a variable-rotation-length approach that allows more timber production than on federal lands, while maintaining a portion of the landscape in older forest. A long-rotation approach, however, was initially considered by FEMAT scientists but rejected because of perceived high risk to terrestrial and aquatic species and ecosystems.

These different perspectives could be further developed into contrasting strategies that would be rigorously compared in large-scale management experiments. Involving people with different perspectives is essential and would allow creative approaches to coalesce and be seriously considered. We also see some opportunity to examine past management retrospectively to shed some light on these ideas.

Considerations

The current Plan course is the net result of the intersection of initial Plan objectives with the realities managers faced along the way. During the first decade of the Plan, we have concluded that the agencies did well, especially for biological objectives. Many expectations for timber production and adaptive management might have been overly optimistic, and perhaps were somewhat unreasonable. Better managing of expectations in the next decades is important. Budget reductions for federal agencies—especially the loss of funds from FS trust accounts, often from revenues generated from timber harvests—led to major reductions in permanent FS employees, which influenced agency capacity. Perhaps a timber program is required to meet the many other important agency functions—like keeping records, maintaining roads, and even providing for recreation and wildlife. We are also concerned whether minimal capacities are being maintained, such as the on-the-ground knowledge of the forest. The main question in the near future may be whether the current federal workforce can carry out the complex management strategies set forth in the Plan, and if such a workforce cannot be assembled, whether a different approach is needed. In the last few years of the Plan, managers appear to be dealing with these problems more successfully, especially with increased thinning volume from plantations in coastal late-successional reserves and fuller funding of and attention to a fully institutionalized and integrated adaptive-management and regional monitoring program.

Science from monitoring and research does not lead to specific prescriptive solutions. The evidence and its collective uncertainties do suggest that we cannot know for certain that another approach (for example, one of the other FEMAT alternatives) would have done better or worse than the approach applied, which is not to say that all approaches work equally well. In general, we think the goals of the Plan cannot be met by returning to the timber harvest rates in the mid-1980s or converting the FS and BLM lands into de facto national parks. The historical harvest rates would have quickly cut most old stands and impaired critical habitat for important late-successional and aquatic species, and continue to be unsupportable by current case law. Eliminating commercial harvest from the federal lands would not be in the interest of the timber-dependent communities or others, especially in fire-prone areas or forests requiring considerable institutional or financial resources to meet other objectives. Our understanding of ecological and social processes, their interactions, and their collective uncertainties suggests that a **range** of middle courses exists that is reasonably consistent with what we understand about how these forest ecosystems work. Middle courses might be found, not by more science, but by developing a new, positive vision of how the federal forests can meet diverse societal goals, rather than focusing on meeting regional standards and guidelines. Improving adaptive management and monitoring, risk management, and record keeping can increase the effectiveness of these middle courses and provide a more solid foundation for connecting to the diverse constituencies in the region.

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Chapter 4: Progress to Date

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Introduction

The inferences and opinions expressed in this report attest to the complex nature of the Northwest Forest Plan (the Plan) and its far-reaching effects on the socioeconomic and ecological fabric of the Pacific Northwest. Progress to date can be summarized by addressing four interconnected questions:

- Has the Plan resulted in changes that are consistent with objectives identified by President Clinton?
- Are major assumptions behind the Plan still valid?
- Have we advanced learning through monitoring and adaptive management?
- Does the Plan provide robust direction for the future?

Measurable Progress

President Clinton challenged federal agencies to work together to develop a scientifically credible plan to protect the long-term ecological health of federally managed forests, while providing sustainable levels of forest products that would contribute to the economic stability of the region. Has the Plan resulted in changes that are consistent with the objectives identified by President Clinton? Ten years after it was initiated is too soon to judge whether it has been fully successful, but some trends are clear.

The most notable accomplishments are associated with protecting late-successional and old-growth forest, termed older forest, and riparian forests and associated species. Harvest of trees in older forest and riparian areas has dwindled to insignificant amounts compared to historical harvest rates. The Plan protects most existing old-growth stands from future harvest, and other midseral stands are slowly developing old-growth characteristics, such as large trees and multistoried canopies. Other successes include active watershed restoration and decommissioning of roads, site-specific protection of sensitive species, improved watershed planning processes, increased understanding of the distribution and habitat needs of species of concern, and advancing silvicultural practices to accelerate old-growth development.

The Plan also fell short in some arenas, most notably in providing for a “predictable and sustainable level of timber sales and nontimber resources” and “new economic opportunities for year-round, high-wage, high-skill jobs” (FEMAT 1993, chapter 3). Specifically, timber harvest rates were lower than expected. Current overall harvest rates likely can be sustained, but only if the mix of harvest prescriptions changes through time to match changes in the structural composition of forests. Timber shortfalls resulted in economic hardship for some communities, but others were able to compensate by increases in other economic sectors and through active civic leadership. Active fuels management in the drier forests of the eastern Cascades and Klamath-Siskiyou regions lagged behind expectations, perhaps increasing the risk of uncharacteristic large or severe fire in these regions. Large fires, such as the Megram Fire in 1999 (125,000 acres) and the Biscuit Fire in 2002 (500,000 acres), resulted in substantial losses of older forests and local increases in watershed degradation, but disturbance rates averaged over the Plan area were consistent with expectations.

The Plan failed to fully end “the gridlock within the federal government,” although increases in cooperation among federal agencies and between research and management were noticeable. An understandable lack of consensus among stakeholders and the agencies contributes to continuing stalemate in some areas.

Nan Vance

Bruce Marcot

Richard Haynes

A variety of forest products contribute to human well-being: bear grass and salal used as floral greens, mushrooms both as a cash crop and as a food; Douglas-fir for softwood lumber.

Validity of Assumptions

The Plan rested on many wide-ranging assumptions either explicitly identified in planning documents or implied through the Plan's direction and expectations. Various lines of evidence support the veracity of many of these assumptions, yet others have been challenged by new findings or emerging knowledge. Testing and refining assumptions is a critical step toward improved understanding and ability to manage effectively.

Many Assumptions Remain Valid

One of the Plan's central assumptions was that old-growth forests (especially those with older forest structure) were limited in distribution and that the network of reserves identified in the Plan would encompass most of the remaining old growth. Updated (and more accurate) inventories are remarkably consistent with pre-Plan regional estimates of old-growth forest and reaffirm the assumed overlap of old growth and the reserve network (chapter 6). The network of late-successional reserves and congressionally reserved areas was also assumed to include most of the best remaining habitat for northern spotted owls (see appendix for species names) and other old-growth-dependent species. Recent estimates identified 10.3 million acres of owl habitat in these areas, representing 59 percent of the owl habitat available on federal land (Davis and Lint 2005). Owl habitat also was thought to be an adequate surrogate for marbled murrelet habitat where the two species overlap, and it was assumed that the Plan reserve strategy would include 86 percent of the federally controlled murrelet nesting habitat. Improved modeling of murrelet habitat has produced similar estimates (81 percent), suggesting that the original planners successfully identified much of the nesting habitat on federal lands. Whether protection of habitat has halted declines in owl or murrelet numbers is a complex and as yet unanswered question (chapter 7).

In a similar context, key watersheds that were assumed to be in better condition than most were identified as part of the Aquatic Conservation Strategy (ACS). The aquatic monitoring effort demonstrated that key watersheds generally have fewer roads and higher rates of road decommissioning, which accounts for higher condition scores (Gallo and others 2005). The aquatic strategy was designed by using a body of science that pointed to the dynamic interconnections of riparian vegetation, large wood, sediment, and landscape disturbance. Subsequent research has further strengthened the underlying assumptions of the ACS (chapter 9).

Monitoring results reinforce several other key assumptions of the Plan. For example, forest inventory data abundantly demonstrate that trees can grow quickly in the productive forests of the Pacific Northwest. Increases in mean tree diameter in undisturbed stands suggest that old-growth forests are being naturally recruited, with positive implications for both terrestrial and aquatic species. It is still unknown how rapidly these new old-growth forests will acquire the structure of older forests.

Experimental thinning in plantations demonstrated that some old-growth features, such as large trees and spatial heterogeneity, could develop more rapidly following treatment; other features, such as species diversity, may simply require time (chapter 6). The implications of accelerated development are not fully understood. Clearly, many species are associated with old-growth forests, but whether they respond solely to structure or to more time-dependent processes (dispersal, for example) is often unknown.

Two of the more controversial issues in the Plan include the permanency of reserve boundaries and salvage logging in reserves. The Plan assumed that reserve networks would be large enough to withstand large disturbances without loss of function. Thus far, that assumption seems to hold true. That fixed reserves are an optimal strategy for conserving biodiversity in the long term remains an untested assumption. Indeed, testing such a broad-scale, long-term hypothesis is not possible in a short time. In chapter 6, we note that the direction for salvage logging in late-successional reserves was unclear, but left open the possibility of limited salvage logging for commercial purposes. An underlying assumption was that the rationale for salvage logging was primarily economic, not ecological, and little salvage in reserves would occur. Emerging science findings confirm assumptions about the ecological functions of downed wood and large snags following wildfire. Retention of large, dead tress following stand-replacing wildfire provides long-term benefits consistent with the ecological goals of the Plan.

Unsupported Assumptions

Several assumptions incorporated into the Plan have since shown to be unsupported, or only weakly supported, by new evidence or understanding. Assumptions were challenged regarding both socioeconomic and ecological relations, with implications for both. One of the more important findings concerns the role of the federally managed lands. From a socioeconomic perspective, it was assumed that timber flow from federal lands was a key determinant of community well-being. As discussed in chapter 5, this is true in some communities. Looking more broadly, the presumption that federal land would continue to be a major supplier of high-grade commercial timber is questionable. The dominant social values expressed in forest management may have changed since Plan inception. For example, lawsuits, threats of lawsuits, and protest regarding harvest of old-growth forest in matrix areas or thinning older forest in reserves has resulted in lower-than-anticipated harvest levels, and have slowed the pace of active management. The results include unanticipated amounts of old growth remaining in matrix areas and elevated risk of uncharacteristic severe fire in dry forests, with positive and negative implications for species of concern. Post-Plan information on species' distributions and habitat preferences can aid local or regional assessments of whether old-growth harvest in matrix areas or additional fuel treatments in dry forest threaten species viability.

Experience with the Plan has led to important changes in how ecosystem processes are viewed and the applicability of various conservation paradigms. For example, the northern spotted owl was used as an umbrella species; it was assumed that conserving the habitat of spotted owls would provide for the needs of many other old-growth-dependent species. Because of the Survey and Manage program, we now recognize that a single-species focus may not be effective for all old-growth-related species, and that more holistic strategies may be required. The identification of barred owls and West Nile virus as potential threats to northern spotted owls demonstrates that providing habitat is a necessary but not sufficient condition for conserving species. That disturbance is an important component of ecosystem productivity and biological diversity is increasingly recognized; positive long-term benefits can arise from episodic disturbances at a variety of spatial and temporal scales.

Advances in Learning

Many of the issues involved in monitoring and adaptive management discussed in chapter 10 are briefly summarized here by asking, "Have monitoring and adaptive management advanced learning?" Overall, the answer is a qualified yes. Some notable successes were achieved, but also some failures; improvements are possible in places.

Without question, the monitoring program produced a wealth of data and information. Major improvements in remote sensing and forest inventories provide a detailed picture of current forest conditions throughout the Plan area and allow tracking of changes in these forests. Species surveys and population monitoring aid understanding of the distribution and habitat needs of many species and provide indicators of change for select species. Because of the Survey and Manage program, for example, more than 67,000 species locations were mapped—an unparalleled achievement for a monitoring program over a similar-sized area. The northern spotted owl monitoring program is one of the most intensive avian population monitoring efforts in North America. The aquatic and riparian monitoring effort is systematically building a database on riparian and instream conditions that is amenable to both monitoring and exploring linkages among ecological drivers and responses at multiple spatial scales. Despite its late start, the socioeconomic program has produced findings that aid understanding of the large-scale context of the Plan, as well as its regional and local impacts.

Room for improvement can be found, however, even in the most successful programs. Some efforts are still in nascent phases; judging their ultimate success is difficult. Funding shortfalls and disagreements on design slowed implementation of the aquatic and riparian monitoring program. The marbled murrelet monitoring effort also took time to get underway, which limits the time series available for analysis. A general plan for monitoring biodiversity was not developed; even defining biodiversity pragmatically is difficult (chapter 8). Inconsistencies between agencies and administrative units continue to impede integration of data in multiple ways. For example, differences in remote sensing and classification methods created problems in developing a seamless vegetation map stretching from California to Oregon and Washington.

Experimental management has produced useful, but spotty, results. Much of the success has come from stand-level experiments such as variable-density thinning in plantations or combinations of prescribed fire and thinning in experimental forests. Rigorous broad-scale experiments were lacking. Experience with adaptive management areas is generally disappointing, because they have not facilitated the degree of innovation and experimentation expected. Too often, precaution seems to have trumped learning. As discussed in chapter 10, carefully focused questions, quantifiable expectations, efficient monitoring, and well-structured comparisons could accelerate learning.

Looking to the Future

Invariably, the question arises as to whether observations of the past decade provide evidence that the Plan is or is not working and warrants revision. Science alone cannot offer a definitive answer to this question, nor should it. To assert that the Plan is working requires subjective judgments for which no consensus exists. The Plan is too complex and diverse to give it a simple pass-fail grade. Clearly, some expectations of the Plan have been met more successfully than others, but it is too early or too difficult to judge most outcomes. How the Plan is ultimately judged depends on expectations, the value assigned to its various components and consequences, and beliefs about the possible performance of alternative strategies. Judging the Plan is much like trying to evaluate the performance of a sports team early in the season when team cohesion is weak and their strengths and weaknesses have not been fully tested nor revealed and observers have their own criteria for declaring success.

Various observations on the Plan and its ability to help federal agencies address major management challenges are reviewed below. These observations are organized by the types of problems that characterize particular issues, rather than by topical areas. The various issues and their similarities are assessed in terms of appropriate scale, temporal tradeoffs, or interactions between pattern and process. Finally, the Plan's flexibility to address a range of issues is examined.

Appropriate Scale

The importance of spatial scale is an oft-repeated theme in this report. That is, every major issue has its own characteristic scale or mix of scales. Mismatches between the scale of a management response and the characteristic scale of the issue can contribute to ineffective management. For example, the Plan is addressed exclusively at federally managed lands. For socioeconomic issues, federal lands are a small part of local, regional, and even international economies. Thus, trying to anticipate or assess the Plan's effects without looking at the larger context is illogical. On the ecological side, wide-ranging species like anadromous salmon and marbled murrelets cannot be managed effectively on federal land alone. Other issues like invasive species and wildland fire do not recognize administrative boundaries. Federally managed land is vital to solving wide-ranging problems, but overall societal goals cannot be met by partial fixes. Therefore, integrating the Plan with transboundary planning efforts such as the National Fire

Plan, the Northwest Power Planning Council's fish and wildlife program, or other state and federal efforts can help build partnerships essential for success.

Below the level of transboundary problems, other spatial-scale issues fall wholly within the federal estate. Chapter 6 touches on the linkages between size and distribution of reserves and the purposes they are intended to serve. Limited historical evidence suggests that they are large enough to be resilient to certain types of disturbance, but hardly impervious. Chapters 8 and 9 discuss the role of complementary coarse- and fine-scale filters in species conservation. The lesson is that some species may fall through the cracks of a coarse-scale policy that expects large reserves to meet the needs of all species. Some level of fine-scale protection of unique habitats or even of individuals (for example, nesting pairs of owls) may be required. Chapter 9 also discusses the importance of managing within watersheds by looking across a range of stream sizes and upstream-downstream and upslope-riparian perspectives, and discusses that broad-scale strategy of managing for a range of watershed conditions. Chapter 3 identifies the lack of mid-scale planning to help match the Plan's strategic direction to an appropriate scale of action.

Temporal Tradeoffs

The questions of appropriate spatial scale are paralleled by issues of temporal scale. One pervasive issue is that of the tradeoffs between short- and long-term consequences. This issue is particularly acute when a short-term impact (or benefit) is highly probable but small, relative to a less likely but more substantial long-term benefit (or impact). The classic example is fuel management in fire-prone ecosystems; the negative short-term effects on sensitive species such as spotted owls can be balanced against possible long-term benefits of reduced losses in habitat to high-severity fire. A second example is salvage logging. Salvage logging may provide short-term economic gain and reduce fuel loads (depending on methods), but also may have long-term consequences for soil compaction, erosion, or loss of unique early successional habitats containing large downed wood and snags (chapter 6). Indeed, the more general question of active management versus passive protection invariably invokes temporal comparisons. As discussed in chapter 10, simple rules such as the precautionary principle do not assure an optimal solution.

Moreover, temporal tradeoffs are implicit in decisions about agency organization, staffing, training, and investment in research or learning. Just as physical infrastructure constrains management options, the same is true of social capital, agency technical capacity, knowledge, and technology. Major reductions in agency workforce affect the ability to plan and implement projects. Federal workforce reductions also affect rural communities, where federal workers may be some of the more highly educated and influential residents (chapter 5). The discussion in chapters 3 and 10 regarding agency capacity for adaptive management and midscale planning reinforce a basic truth—you cannot build a trustworthy ship without shipwrights.

Science played a major role in shaping the Plan, and scientists continued to be active in implementing, monitoring, and assessing its effects. A shift toward advanced technologies (for example, internet, geographic information system, and remote sensing) has improved efficiency, changed agency operations, and even revamped how federal agencies engage and interact with the public. Management challenges continue to grow and become more complex, however, making prudent investments in research and learning even more critical. Such investments reflect additional tradeoffs between short- and long-term gains. Funds invested in monitoring and research are not available for other uses nor can the benefits be guaranteed. In these cases, we need to be sensitive to the information needs of management (and society in general), and identify explicitly the expected benefits and risks of investments in research and monitoring.

Pattern and Process

A third—and perhaps most daunting—set of problems in ecosystem management involves interactions between pattern and process. Similar to the issues of appropriate scale, pattern and process are intertwined concepts for describing, understanding, and managing landscapes—with a temporal twist. Pattern, the spatial arrangement of landscape components, is a consequence of process, the interactions between ecological components acting on a landscape. Just as pattern results from processes, processes are also constrained by pattern, but more than just pattern; other ecological components can be involved. An example is wildland fire. Fire acts in concert with other processes to shape spatial patterns of vegetation structure. Conversely, the expression of fire on a landscape is constrained by vegetational patterns and topography. The challenge is that these processes are often not directly observable and they are inferred from landscape patterns. Managers face a more difficult challenge in that they use processes to shape pattern, hoping that the patterns they create will affect other processes outside of their direct control. For example, agencies use prescribed fire and thinning to create fuel breaks intended to alter wildland fire behavior, such that areas of concern do not burn or else burn at low intensity.

Pileated woodpeckers have excavated many feeding cavities in this old-growth Douglas-fir tree. The ecological roles of pileated woodpeckers include creating cavities that many other species use for breeding and hiding; physically breaking apart snags and down logs, which helps accelerate the return of organic matter into the soil; and creating wood and bark piles at the base of snags, which are used by other organisms including salamanders, lizards, and snakes.

Several of the more challenging topics addressed in this report involve interactions of pattern and process. One example is the relation between forest development (succession) and disturbance. Understanding of how individual trees, stands, and even complex landscapes develop in ways that either retard or encourage certain types of disturbance is evolving. The variety and distribution of old-growth characteristics described in chapter 6 are derived in part by such interactions at multiple scales. Another example is the interaction of terrestrial disturbances and stream-channel dynamics discussed in chapter 9. Invasive species and disease are additional issues that invariably include interacting processes affected by pattern.

The challenges of understanding and managing spatial pattern and processes come to the fore throughout the Plan, but nowhere more critically than in designating land allocations. The Plan may represent new thinking in resource management, but its primary mechanism is one of the oldest tricks in the book—multiple-use management by dominant-use zoning. Because of the Plan, the federal estate can be viewed as a collage of overlapping land-use designations, with each designation bringing its own set of standards and guidelines, and a second set describing which directions take priority. Thus a single landscape can have late-successional reserves, key watersheds, riparian reserves, congressionally reserved lands, adaptive management areas, and sundry other special use designations. These make up only the administrative boundaries. The real landscape has its own tapestry of natural features (topography, soil, rainfall, stream networks, vegetation, fauna, and such) intersecting with human elements (like roads, farms, homes, cities, and dams). The administrative designations are expected to dictate human activities that will work with natural processes and existing features to create a desirable landscape pattern of ecological attributes. Presumably, this pattern will constrain natural processes so the desired landscape is sustained for people to enjoy. The old saw, "it isn't rocket science," certainly applies: rocket science is not this hard!

The issue of land allocation segues naturally into conflicts between active and passive management. Many of the land designations are primarily proscriptive; that is, they prohibit activities rather than call for action. As such, they reflect the precautionary principle implemented as a restriction on activities that might have negative effects (chapter 10). To some extent, they also reflect what Hargrove (1994) calls "environmental therapeutic nihilism," a belief that nature is too complex to manage intelligently and thus should be left alone to heal whatever ails it. Other tenets of this philosophy are reflected in the Plan and our assessment of its effectiveness. For example, the discussions of the benefits of natural disturbance in chapters 6 and 9 echo a parallel adage in human health that "whatever doesn't kill you makes you stronger." Although the premises that natural disturbances can be positive and ecosystems have natural recuperative powers have evidentiary support, experience with the Plan also illustrates the limits of such truisms. Every problem does not require active intervention, but some do.

Flexibility Provided by the Plan

The region affected by the Plan is an area of both remarkable similarities and pronounced differences. Traveling north to south or west to east reveals remarkable gradients in climate and topography, with resultant ecological variations in forest types and associated species. Equally remarkable are the socioeconomic differences between large metropolitan areas like Seattle, Washington, and Portland, Oregon, and the resource-dependent rural communities scattered throughout. For someone unfamiliar with the Plan's genesis and its tie to the northern spotted owl, it would seem an odd collection of lands to be grouped under one management plan.

Accommodating the intraregional ecological and socioeconomic diversity has been a major challenge to those designing and implementing the Plan. Opinions differ whether the Plan intended for considerable discretion to adapt standards and guidelines to provincial or site-specific differences, but a reluctance or resistance to change default standards and guidelines is apparent. Flexibility and willingness to use it are essential to matching management actions to local conditions and improving efficiency. Exercising discretion is a standard approach to managing risk. For example, the quickest and safest way to travel between two points is to match your speed to the road conditions, not to drive at a constant speed. Flexibility also can allow for increased experimentation, and hence enhance opportunities for learning, leading to more efficient and effective ways to meet plan objectives.

The Plan represents an ambitious, long-term vision for managing federal lands of the Pacific Northwest, but it remains to be seen how well it can endure. Carrying the vision forward promises to be a continuing challenge; this requires building on the successes of the Plan and improving its shortcomings. Changes in social expectations and values, administrative policies and procedures, and sundry other socioeconomic factors will play out in unforeseen ways. Equally important are the inevitable ecological surprises, such as large-scale disturbances, invasive species, droughts, disease, and climate change that will strain ecosystem resiliency and potentially lead to major shifts in forest communities. In an era of declining federal funding and personnel, management agencies will be further challenged to improve partnerships and collaboration to leverage limited resources to meet growing societal demands. The only prediction that can be made with certainty is that information, knowledge, and creativity will always be essential ingredients for success.

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Part II

Chapter 5: The Socioeconomic Implications of the Northwest Forest Plan

Richard W. Haynes and Elisabeth Grinspoon

Introduction

Socioeconomic issues are at the root of the controversy that led to the development of the Northwest Forest Plan (the Plan) and to the social and economic monitoring questions. This controversy emerged in the late 1950s and revolved around three related issues: the role and amount of federal timber in timber markets; the federal agencies' obligations to maintain communities near or among federal timberlands; and the role forests play, especially federal forests, in regional economies.

These issues were first identified in the mid-1950s as employment declined in the Pacific Northwest forest products industry while harvests remained relatively stable (Smith and Gedney 1965). These trends are shown in figure 5-1a. Jobs per million board feet of harvest declined progressively from 1950 to 1975 (see fig. 5-1b), as the industry modernized mills, shifted from using mostly private timber to using a mix of public and private timber, and diversified to include high-value log export and plywood industries. During the mid-1980s, trends in jobs per million board feet reversed and began increasing to levels higher than in the early 1950s. The reversal in trends was due to changes in the mix of products and increases in production of logs that were formerly exported for processing overseas.

By the 1990s, shifting societal environmental values were changing the objectives for federal forest management[1] to favor increased old growth and habitat protection over timber management on federal forest lands.[2] This shift was manifest in the Dwyer ruling, the forest conference, and the development of the Plan (see chapter 1 for more details). The Plan was adopted with the expectations that it would settle conflicts over federal forests and lead to a new era in resource management.

One other notable aspect to this evolving debate was that social questions became included in public debates about forest policy. As Clark and others (1999) observed, the 1993 forest conference held in Portland, Oregon, that led to the development of the Plan marked the first time that social scientists were invited to participate in national forest policy debates. The Plan reflects the inclusion of social scientists and citizens in its formation since it was guided by the principles spelled out by President Clinton who reminded us that forest management is a social problem, embodying questions of how society chooses among possible futures.

[1] Forest management is at heart a process of managing a stand, collection of stands, or a forest to meet the objectives of the landowners. For private forest land owners, particularly those interested in financial returns (timber is considered a capital asset and part of an individual's portfolio of investments), their objectives often center on producing marketable goods, such as timber, hunting rights, and selected nontimber forest products like floral greens, in an environmentally sound way. Public forest land managers typically have broader sets of objectives including producing both market and nonmarket goods.

[2] In the United States, retaining some forest lands (71 percent is private and 29 percent is publicly owned) in public ownership has been one attempt to impose broader management goals than what might be expected from just market actions.

Employment

Employment has been a key issue in forest policy discussions since the late 1960s. The issue arose in the mid-1950s when employment declined in the forest products industry while harvests were relatively stable (Smith and Gedney 1965). Further employment declines in the late 1950s and early 1960s raised policy questions about how to manage employment instability in a sector that was a major source of income and employment in Washington, Oregon, and California. The ensuing policy discussions set the context for many policy debates that shaped the Forest Ecosystem Management Assessment Team (FEMAT) report (FEMAT 1993) and the Plan (as implemented by the record of decision, USDA and USDI 1994b). In 1975, Wall and Oswald summarized these policy discussions as:

- Employment instability can cause severe hardships on individuals and families and economic distress in local and regional economies.
- High rates of timber harvest and product output from Washington, Oregon, and California that have been sustained by harvest of old growth cannot be sustained in the future.
- Diminished timber availability will result as more alternative uses of forest land are considered.
- Prospects for tightened timber supplies from Washington, Oregon, and California reduce the competitiveness of locally produced wood products in national and international markets, with potential regional economic and community effects.

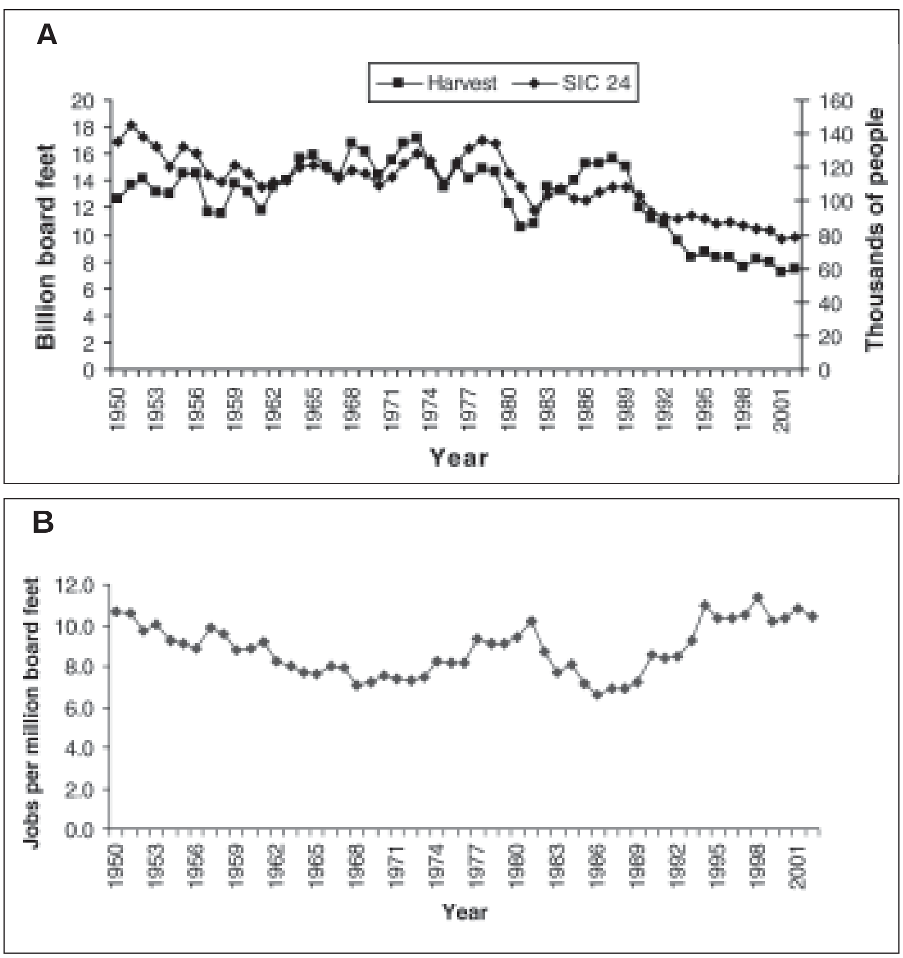

Figure 5-1—(a) Employment and harvest for Pacific Northwest, (b) jobs per million board feet of harvest in the Pacific Northwest. SIC 24 = Standard Industrial Classification for lumber and wood products. Source: 1950-1965 Smith and Gedney 1965, 1966-2002 from Warren 2004.

Assessment of Social and Economic Trends Associated With the Plan

The Five Socioeconomic Monitoring Questions

At the forest conference, President Clinton enumerated five principles to guide the development of the Plan. These principles emphasize social and economic components, including new economic opportunities for year-round, high-wage, high-skill jobs; protecting the forests for future generations; legal responsibility; predictable and sustainable levels of timber sales; and collaboration among federal agencies for the public good (FEMAT 1993: ii).

To measure progress toward implementing the Plan, the record of decision (ROD) (USDA and USDI 1994b) included a monitoring and evaluation plan. Three of the questions it posed focus on socioeconomic issues. The first relates to rates of using natural resources: Are predictable levels of timber[3] and nontimber resources available and being produced? The ROD specifies seven key items to monitor to answer this question: timber harvest rates, special forest products (like mushrooms, boughs, and ferns), livestock grazing, mineral extraction, recreation, scenic quality (including air quality), and commercial fishing.

The second question relates to rural economies and communities: Are local communities and economies experiencing positive or negative changes that may be associated with federal forest management? The ROD (USDA and USDI 1994b) specified eight key items to monitor under this question including demographics, employment (timber, recreation, forest products, fishing, mining, and grazing), government revenues (USDA Forest Service [FS] and USDI Bureau of Land Management [BLM] receipts), facilities and infrastructure, social service burden (welfare, poverty, aid to dependent children, and food stamps), federal assistance programs, (loans and grants to states, counties, and communities), business trends (cycles, interest rates, and business openings and closings), and taxes (property, sales, and business).

The third is a set of questions related to American Indians and their culture: For those trust resources identified in treaties with American Indians, what are their conditions and trends? Are sites of religious and cultural heritage adequately protected? Do American Indians have access to and use of forest species, resources, and places important for cultural, subsistence, or economic reasons, particularly those identified in treaties? Key monitoring items include conditions and trends of the American Indian trust resources, effectiveness of the coordination or liaison to assure protection of religious or cultural heritage sites, adequacy of access to resources and to the vicinity of religious or cultural sites.

The ROD (USDA and USDI 1994b) did not explicitly identify social and economic goals and objectives for the Plan, but they are described in other Plan-related documents (Pipkin 1998, Tuchmann and others 1996). The monitoring team identified five socioeconomic objectives that could be used to measure progress toward the goals of the Plan.

The objectives are:

1. Produce a predictable and sustainable supply of timber sales, nontimber forest resources, and recreation opportunities that would help meet the second objective.
2. Maintain the stability of local and regional economies on a predictable and long-term basis.
3. Minimize adverse effects on jobs by assisting with economic development and diversification opportunities in those rural communities most affected by the cutbacks in federal timber sales.
4. Establish a system of terrestrial and aquatic reserves that would protect forest values and environmental qualities associated with late-successional, old-growth, and aquatic ecosystems.
5. A new approach to federal forest management in which federal agencies would collaborate and coordinate with one another.

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[3] Predictable level of timber is used here in its generic sense of a known and expected flow of timber.

Evaluating How Well the Plan Performed

In this section we discuss how well federal agencies did in meeting Plan objectives with review of trends in key variables. Information from the socioeconomic status and trends report (Charnley and others 2006a: exec summary) suggests that federal agencies made limited progress in meeting the Plan's socioeconomic objectives. The BLM was more successful than the FS in providing a stable flow of socioeconomic benefits to communities in the Plan area because the budgets of the BLM field units rose over the past 10 years, while those of the FS fell. Thus the BLM had resources to invest in new ecosystem management activities that were aligned with Plan goals such as recreation and restoration that provided local communities with some socioeconomic benefits. The FS field units, on the other hand, encountered problems in maintaining basic management activities. What was expected from each objective and what actually happened in implementing the Plan is summarized in table 5-1. It also shows the differences between the two.

Produce a predictable timber supply—
The general expectation was that the Plan would produce a reduced, yet predictable supply of timber from the national forests in the range of the northern spotted owl (see appendix for scientific names). In 1994, the *Northwest Forest Plan Final Supplemental Environmental Impact Statement* (FSEIS) (USDA and USDI 1994a) estimated an average annual probable sale quantity (PSQ[4]) of 958 million board feet of timber annually. The FS reduced the PSQ several times after 1994. Despite the reduced PSQ, the average annual volume of federal timber produced in the Plan area during the first decade of Plan implementation (1994-2004) averaged only 34 percent of the expected annual PSQ for the decade. From data collected for the socioeconomic monitoring report, this difference was attributed to the time required for agencies to complete the surveys and assessments required by the Plan as well as to prepare sales consistent with the standards and guidelines (USDA and USDI 1994b).

The relations among timber offered, sold, and cut as well as the uncut volume under contract for the "owl forests"[5] in Pacific Southwest Region (Region 5) and Pacific Northwest Region (Region 6) are shown in figures 5-2a and 5-2b. During the 1990s, national forest harvests (also called cut) fell 96 percent in Region 6 and 90 percent in Region 5. These declines followed similar reductions in timber offered for sale. To complicate the decline in timber volumes, the quality of timber sold also declined. Evidence of this decline is the change in the relation in stumpage prices for timber sold by various public agencies. Until the early 1990s, the FS sold a mix of logs for the domestic market. The price averaged 83 percent of the log mix sold by Oregon and Washington state agencies. Recent sales not only are a fraction of former ones but also are of lower quality, as shown by stumpage prices that average 56 percent of those of the two state agencies.[6]

The timing of the effects associated with federal harvest reductions were mitigated somewhat by the uncut volume under contract (see figs. 5-2a and 5-2b). This uncut volume, small increases in private timber harvest, and a decline in log exports all mitigated the effects of the reduction in federal harvest. The nontimber forest products industry also experienced reductions in the export markets because of downward changes starting in 1997 in Asian economies that have generally reduced prices for some products. In addition, the labor forces used to gather floral greens have

[4] The PSQ is the average annual estimate of the amount of timber that can be produced in the current decade and in every succeeding decade into perpetuity.

[5] The "owl forests" in the Pacific Northwest Region are the Gifford-Pinchot, Mount Baker-Snoqualmie, Mount Hood, Olympic, Rogue River, Siskiyou, Siuslaw, Umpqua, and Willamette. In the Pacific Southwest Region, the owl forests include the Klamath, Mendocino, Six Rivers, and Shasta-Trinity.

[6] This comparison assumes that logging costs and difficulties are similar for both types of sales. If logging costs are higher for federal sales (because of different requirements), federal stumpage prices would be lower than for the other public land agencies. All data are from Warren 2004.

Table 5-1–Expectations versus results (five objectives) regionwide

Objectives	Expected	Occurred	Differences	Differences caused by the Plan	Differences caused by trends unrelated to the Plan
1. Produce predictable supply of timber sales, nontimber resources, and recreation opportunities	Federal agencies offer volumes of timber at probable sale quantity (PSQ) and produce a predictable supply of timber and other goods.	Federal agencies did not meet average annual PSQs over the decade. Grazing and mineral activity declined. Recreation opportunities remained relatively consistent.	Timber output was not produced at predicted volumes. Quantity of special forest products and grazing opportunities declined.	Executive, legislative, and judicial actions reduced the Plan area available for timber production. Access restrictions impacted other activities.	Variability in timber and nontimber products markets led to changes in amounts of special forest products sold. Structural shifts in timber and beef industries affected grazing.
2. Maintain community stability and contribute to community well-being	Community well-being is maintained by providing an even flow of goods from federal forests, including timber, nontimber forest products, services, and jobs.	Regionally, changes occurred for many communities.Well-being increased for about 1/3 of communities, decreased for another 1/3, and remained the same for the rest.	Community well-being was not as dependent on providing an even flow of goods from forests in most communities as expected.	For some communities, decline in timber production caused hardship.	Growth in population occurred at the same time as the increases in educational attainment. Some communities were more resilient than others.
3. Assist with long-term economic development and diversification to minimize adverse impacts associated with job loss	Where timber sales could not proceed, NEAI[a] would provide immediate and long-term assistance to minimize adverse impacts associated with job loss.	The number of timber industry jobs lost exceeded expectations. NEAI provided less help to displaced workers than expected.	Loss of agency jobs caused a significant decline in social capital in forest communities. The Jobs-in-the-Woods program was not as effective as planned.	Greater declines in federal workforce than expected. Restoration activities were not carried out as vigorously as planned.	Agency budgets declined. Changes in other state programs affected economic development. The continuing diversification of the U.S. economy has local impacts.

Table 5-1–Expectations versus results (five objectives) regionwide (continued)

Objectives	Expected	Occurred	Differences	Differences caused by the Plan	Differences caused by trends unrelated to the Plan
4. Protect forest values and economic qualities associated with late-successional old-growth and aquatic ecosystems	Reduce litigation, appeals, gridlock over forest management actions by protecting the uses and values that people associate with these ecosystems.	The uses and values that urban people associate with forests were protected. The uses and values that rural people associate with forests were not protected as well. All "old growth" was not protected.	Gridlock increased because the Plan failed to engender public trust.	Plan raised public expectations for habitat conservation and passive forest management.	Rural urban environmental values continue to evolve. Growing emphasis on sustainable forest management.
5. Promote interagency collaboration and agency-citizen collaboration in forest management	Enhanced collaboration among federal agencies and between agencies and citizens in resource management.	Public engagement in new forums of collaboration delivered benefits to communities. Interagency collaboration improved.	Some citizens were disappointed in the loss of local control in decisions.	Regionwide focus of the Plan diminished the importance of local issues and local constituencies.	Broadening public interest in environmental conservation has increased the interest in collaborative approaches.

[a] NEAI = Northwest Economic Adjustment Initiative.

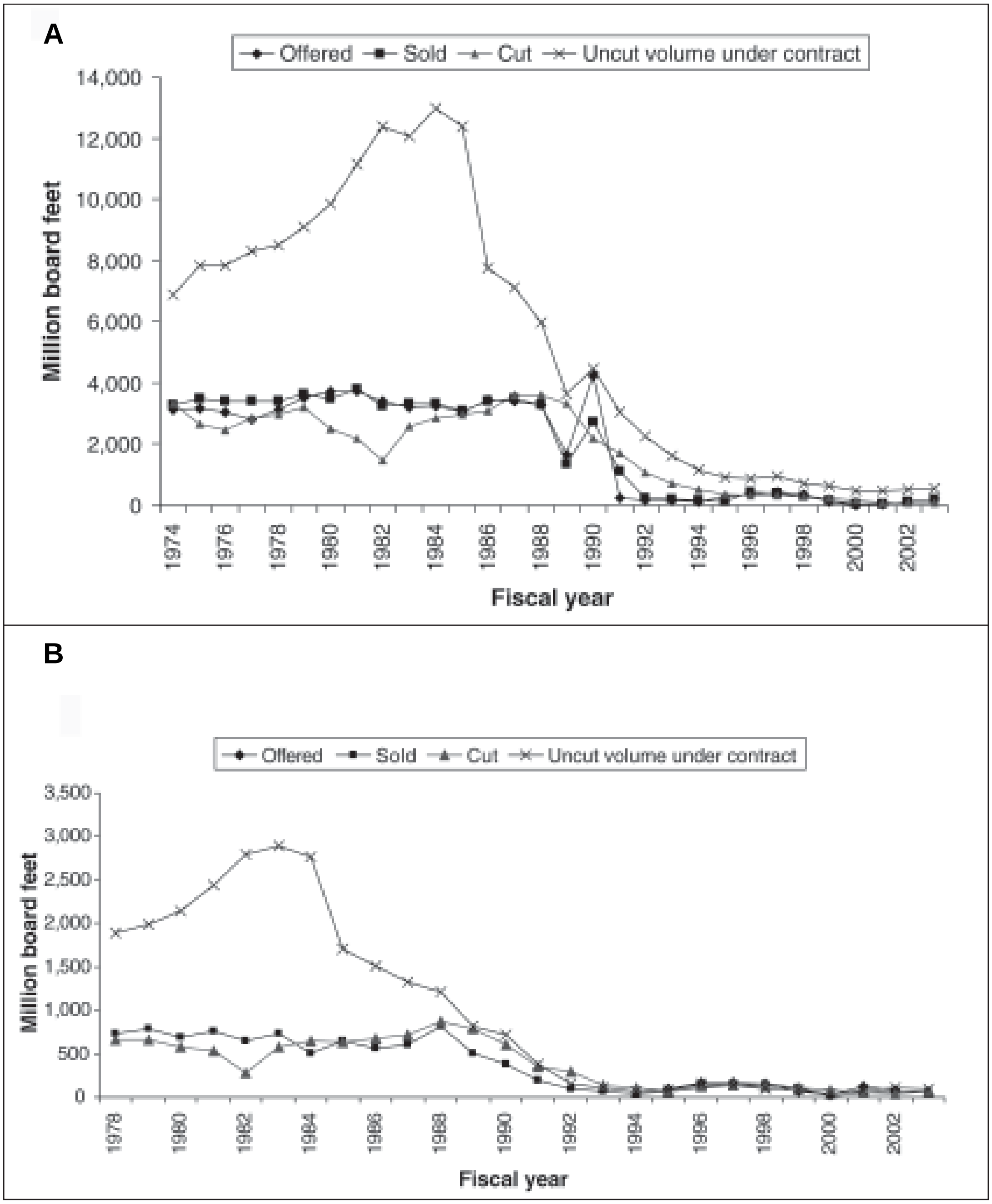

Figure 5-2—(a) Forest Service Pacific Northwest Region “owl forests” timber activity (Source: Warren 2004); (b) Pacific Southwest Region “owl forests” timber activity. In (b), offered and uncut volumes are for calendar year, not fiscal year.

changed significantly (see Lynch and McLain 2003), further reducing local employment opportunities.

Maintain community stability–

Much of the debate about the details of the Plan were based on the assumption that reductions in federal timber flows would reduce local employment opportunities, thereby negatively affecting socioeconomic well-being and threatening community stability. The impacts were mixed as some communities adjacent to federal forest land experienced decreases in socioeconomic well-being and others found ways to adapt to declines in timber production and other changes in social and economic conditions.[7]

The problems of communities near FS land were exacerbated by the direct loss of FS jobs. Many FS employees were active community members serving in various roles. The loss of employment opportunities (either direct employment in the forest products industry or working for the FS) negatively affected the capacity of communities to cope with the social and economic transitions associated with the Plan. In some areas where timber jobs were lost, the departure of timber workers caused families to break apart across generational lines when younger workers had to leave their homes to find work in other areas. Summaries of the interviews conducted as part of the socioeconomic status and trends reports (Charnley and others 2006b) reveal, after a decade, that grief, anxiety, frustration, and anger accompanied this change.

Although community well-being has changed at the regional-scale, it did not change as Plan opponents claimed it would. In the Plan area, 36 percent of communities enjoyed increases in well-being and 37 percent experienced decreases (see Charnley and others 2006b, for details). The rest of the communities remained constant. At the regional scale, some of the potentially negative economic changes associated with the Plan were obscured by rapid growth in population. Total population grew at a rate faster than did the rest of the United States. Increases in educational attainment and household income are also increasing as poverty is decreasing. These positive changes may be related to the attractive natural landscapes that draw new people seeking the natural amenities to the Pacific Northwest.

Richard Haynes

Stevenson, Washington, revamped downtown, ready to host tourists to the Columbia River Gorge National Scenic Area.

Some of the community impacts were mitigated by the Secure Rural Schools and Community Self-Determination Act (2000) (P.L. 106), which provides payments to counties that historically shared revenues from goods and services sold from FS land. The Secure Rural Schools Act replaced past dependence on timber-harvest revenues and has generally mitigated the lost revenues associated with the declines in federal timber harvest in the region (see Phillips 2006).

Assist with economic development–

A key component of the implemented Plan was an explicit attempt to mitigate the social and economic consequences of reduced federal timber flows. Much of this effort was through the Economic Adjustment Initiative, which focused the agencies on considering their role in the long-term economic development and diversification in the Plan region. Christensen and others (1999), Kusel (2002), and Tuchmann and others (1996) described the successes and shortcomings of the initiative. For some communities, the

[7] This increased focus on adaptation and communities in transition will be discussed later; see Donoghue 2003, Donoghue and Haynes 2002 for additional details.

initiative provided economic assistance that went far beyond face value of the dollars it provided. Some communities were able to use Rural Community Assistance grants to leverage money from other sources. The way that the initiative was administered also facilitated new collaborative relations to form between the agency and communities.

Efforts to diversify the economies of the Pacific Northwest were largely implemented through various state programs, but outcomes have been difficult to determine given the economic growth and diversification of the United States and regional economies. A decade later, strategies for economic development have evolved that challenge the earlier approaches of attempting to replace lost wood product manufacturing jobs with other manufacturing jobs. Economic development strategies now consider growing all sectors of functional economies.

Protect forest values—

The Plan was a product of the changing scientific and legal basis for managing forests for habitat conservation goals, but it may not have adequately considered the increasing interest in forest protection among the American public. These changing societal values such as those revealed in the evolving definitions of old growth, as well as its use in increasingly more generic form, contributes to increased gridlock on federal timberlands. Recent surveys indicate the American public generally favors increased protection of federal lands more than do federal land managers, who are responsible for the management of these lands (Kennedy and others 2005, Shields and others 2002, Taylor 2002).

Surveys show that these values are relatively the same for both urban and rural residents with the exception of differences in who controls decisions. Rural residents want to be able to control decisions in their own area, whereas urban residents are more willing to rely on more central decisionmaking and control. The monitoring results reveal this difference where a majority of the interviewees expressed concern over their loss of influence in decisionmaking in activities that affect their local situation.

Promote collaboration–

In general, enhanced collaboration among federal agencies was demonstrated by the Regional Ecosystem Office (REO) and other overarching institutions created by the Plan. Although interagency collaboration has improved, multiscaled planning has been slower to evolve. Most planning energy was expended by local land managers struggling to situate their management activities in the Plan's context as a whole. The next generation of FS and BLM unit planning is getting underway offering opportunities to strengthern midscale planning activities that can help explain the location and timing of specific management practices.

Collaboration between federal agencies and local communities initially showed promise. Their potential for success, however, was diminished when federal officials were required to withdraw temporarily because of the adjudication and the chartering process associated with the 1972 Federal Advisory Committee Act [FACA]. Even though the withdrawal of federal participants was temporary, trust in collaborative processes seems to have been damaged.

Some evidence was shown toward increasingly positive and more frequent collaboration between American Indian and federal land managers. Also provincial advisory committees have advanced interagency collaboration and coordination providing a forum for ongoing multiparty discussions of forest management issues. These and other types of discussions seem not to have met expectations for engaging the public in new forms of collaboration that deliver benefits to communities. Mixed results from collaboration has put public trust of land managers at risk.

Tribal

Relations between tribes and federal land management agencies improved as a result of the Plan. The ROD (USDA and USDI 1994b) provides "a higher level of protection for American Indian trust resources on public lands than the forest plans that it amends, and does not impair or restrict the treaties or rights of the tribes." These higher rates of protection are consistent with efforts in the 1990s to build effective processes for government-to-government relations with American Indian tribal governments.[8] They also underlie the three monitoring questions addressed in the pilot study undertaken in 2000. The questions were:

- How well and to what degree is government-to-government consultation being conducted under the Plan?
- Have the goals and objectives of the consultation been achieved?
- Is the consultation occurring because of effects on resources of tribal interest on federal lands or trust resources on tribal lands?

Judy Mikowski

To provide for the well-being of tribal members, the Coquille Indian Tribe converted a former Weyerhaeuser mill to a casino in Coos Bay, Oregon.

Both the pilot study and various interviews included in the socioeconomic monitoring efforts revealed that although there are numerous definitions of "consultation" and significant differences of opinion as to what constitutes "effective consultation," there have been improved relations among tribes and federal agencies. The interviews also revealed that in some of the case-study communities, the tribes played a significant role in economic development as they built tribal government infrastructure or attempted to diversify economic opportunities for tribal members.

On the Olympic National Forest, for example, collaboration between the Quinault Indian Nation and the forest has been high during the last decade. The Plan's stress on the importance of watershed assessments has prompted interaction and collaboration. A recent land transfer and sharing of revenues generated from another parcel of land also produced legal and administrative ties between the agency and the Quinault Indian Nation that are fueling collaborative efforts.

Tribal communities, like other communities, had members who worked in the timber industry as loggers and mill workers and who lost their jobs in the early 1980s when the regional timber industry began to decline. Interviewed community members believed that the Plan did not cause the decline in the local timber industry, but exacerbated already deteriorating conditions. The flow of socioeconomic benefits to some tribal communities around federal lands declined between 1990 and 2002, however, and strategies to mitigate the losses did not provide substantial benefits.

Are Plan Assumptions and Approaches Still Valid?

Sustainability

One of the key assumptions underlying the Plan was that it would promote sustainable resource flows and conditions. The basis for our understanding of sustainability, however, has changed over the last decade. On public lands, we progressed from forest regulation based on sustained yield forestry to the adoption of ecosystem management approaches that seek balance among biophysical and socioeconomic goals (see Haynes and others 1996, USDA FS 2005). At broad scale for all forest lands, we saw greater interest in understanding how individual actions contribute

[8] Two examples of such efforts were the executive memorandum on government-to-government relations with American Indian tribal governments. The White House, Office of the Press Secretary (April 29, 1994) and Executive Order 13175—Consultation and coordination with Indian tribal governments Federal Register 65, no. 218. (November 9, 2000). In addition, the tribal mentoring module focused on how Plan implementation improved the effectiveness of the federal-tribal relationship (see Stuart and Martine 2006).

Criteria for Sustainability

The Montréal Process includes seven criteria. Of these, two focus on social and economic issues. Criterion 6 addresses the maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies. Criterion 7 speaks to the legal, institutional, and economic framework for conservation and sustainable management. Within these two criteria are many indicators applicable to measuring how well the Plan met its goals as well as progress toward sustainability.

In terms of Criterion 6, the Plan was successful in maintaining and enhancing some long-term socioeconomic benefits. Specifically, the Plan did not meet its goals for timber production. Recreation opportunities, on the other hand, remained relatively constant. Investment in the forest sector declined sharply. Direct employment in the forest sector also declined. Many communities were viable and adaptable to changing economic conditions, whereas others were not. In some cases, the Plan helped federal agencies meet cultural, social, and spiritual needs.

With respect to Criterion 7, the legal framework (laws, regulations, and guidelines) of the federal government and the Forest Service supported the sustainability goals of the Plan for the most part. On occasion, however, the sustainability goals were hindered by the Plan. For example, the production of a predictable supply of timber was hindered by complicated and overlapping laws and regulations. The Plan institutionalized a framework that supported and enhanced forest and cross-sectoral planning. Finally, the Plan did establish a monitoring program to help measure progress toward achieving broad-scale land management goals.

Although the Plan was considered sustainable when developed in 1994, it would not be judged that way today because today's definition of sustainability includes a focus on increasing economic prosperity and promoting social justice.[*]

[*]As used here, justice deals with a range of concerns including equitable power sharing in decisionmaking, respect for property rights of indigenous communities, alleviation of poverty, and institutional capacity to support the conservation and sustainable management of forests.

to progress toward achieving sustainable forest management.[9] For private forest lands and especially those owned by forest industry, we have seen the integration of sustainability into their management systems using certification programs (such as the Sustainable Forestry Initiative and the Forest Stewardship Council, see Johnson and Walck 2004).

In today's context, elements of the Plan are consistent with components of approaches to sustainable forest management. One aspect has been the emphasis in the Plan on using a range of forums for collaboration. Another aspect has been the consideration of using federal land to achieve habitat conservation goals and to reduce regulatory risks for private landowners. Selecting among the array of social, economic, and institutional indicators in the Montréal Process would be one approach for monitoring how well the Plan met its goals as well as progress toward sustainability.

[9] The United States is a signatory to the Montréal Process Criteria and Indicators (Montréal Process Working Group 1998) for Sustainable Forest Management. The Montréal Process includes seven criteria and 67 indicators and has been used to engage agencies, publics, and advocacy groups in a discussion of what the available data can tell about the status, condition, and trends in U.S. forests (see USDA FS 2004 for more details).

Community Dependency and Adaptability

The Plan's socioeconomic goals assumed that there was a "need for a sustainable supply of timber and other forest products that will help maintain the stability of local and regional economies" (USDA and USDI 1994b). These goals were quickly extended to include the stability of communities—especially rural communities—in the northern spotted owl region.

During the 1980s, the debates surrounding community stability broadened to include discussion of how communities change and the "social contract" between land management agencies and communities. The scientists and interested publics endeavored to assess the extent to which the federal government is obligated by "legal" authority to recognize the standing of members of local communities. Their findings, however, suggested that they could make stronger arguments for the "moral" authority. These arguments were derived from the repeated commitments made to local communities in forest plans and the long-standing policies recognizing the rights of those who depend on federal forest land for their livelihood. These past commitments were embodied in forest-level plans developed in the 1980s.

In the past two decades, however, the terms used to depict communities with distinct connections to forest resources have evolved: community stability, forest dependence, forest-based, community capacity, community resiliency, and now with the Montréal Process, community viability and adaptability. This evolution of terms shows the evolving emphasis on the complex, dynamic, and interrelated aspects of rural communities and the natural resources that surround them. The earliest terms dealt with the limits between improved forest management and stable communities achieved through stable employment. By the late 1980s, concern was raised about the lack of a clear definition of stability and how it might be measured (see Richardson 1996) but the term stability continued to endure in policy debates. A number of efforts have sought alternative terms (see Donoghue and Haynes 2002 for a brief summary) and much interest has currently been focused around concepts like resiliency, capacity, and adaptability.

These new concepts emphasize the ability of a community (defined by a sense of place, organization, or structure) to take advantage of opportunities and deal with change (Doak and Kusel 1996, Harris and others 2000). They are dynamic, just like external factors that might induce change in a community. The evolution of terms suggests that connectivity to broad regional economies, community cohesiveness and place attachment, and civic leadership are greater factors in determining community viability and adaptability than are factors related to employment.

Concurrent with discussions about stability and well-being have been discussions about the term "forest dependence." Dependence was initially defined by employment in forest product production, but various research studies suggest that communities are more complex than traditional measurements would imply (see Haynes and others 1996). Most communities have mixed economies, and their vitality is often linked to factors other than commodity production. Many of the communities thought of as timber dependent have been confronted with economically significant challenges, such as mill closures, and they have displayed resilient behavior dealing with change. Arguments for redefining forest dependence emphasized that the economic ties that some communities have to forests are not wood product-based, but in recreation and other amenities (Kusel 1996). Another concern was that the term "forest dependence" did not reflect the local living traditions and sense of place held by many communities (Kusel 1996). This broader connotation is often what is implied by the term forest-based.

Increased Collaboration

A third underlying assumption was that increased collaboration with diverse stakeholder groups would lead to a consensus (or greater trust) that will allow for actions that can please a wider range of constituents. The past decade has seen improvements in the way in which stakeholders are involved in discussions of forest management decisions. Among the changes is an appreciation that even when people find forest practices acceptable, their judgments are almost always provisional rather than absolute or final (Stankey and others 2003a). These judgments and their durability are affected by people's trust in managers, their personal experience with place, their ideas about what "natural" is, the degree of risk seen in management actions, and people's reliance on their values or experiential knowledge in addition to scientific knowledge. This research suggests that even management decisions and actions supported by sound science will ultimately fail if social acceptance is lacking. The research also suggests several strategies to gain public acceptance (Shindler and others 2002):

- Treat social acceptability as a process, rather than an end product.
- Develop organizational capacity to respond to public concerns.
- Approach trust-building as the central long-term goal of effective public process.
- Provide leadership to develop a shared understanding of forest conditions and practices.
- Focus on the larger context within which forest landscapes are managed, including risks and uncertainties.

In this context, forest management involves managing places that have multiple meanings to different stakeholders. Place-based management requires managers to use processes such as multiparty negotiation and collaboration to give people the chance to express, negotiate, and transform meanings about places. Approaches that recognize the significance of place meanings take time, but they can result in reducing conflicts over resource management saving time in the long run.

There is another aspect to collaboration: in an era of declining budgets, the FS is increasingly relying on partnerships with groups that share similar resource management goals. The Plan area has an extensive but informally linked network of staff working in the partnership arena. This broad network provides a tremendous asset by enhancing the effectiveness and delivery of regional programs of work. The paradox is that budget declines serve as an incentive for expansion of collaborative processes, but when these declines reduce agency capacity, they may also jeopardize collaborative efforts.

Federal Lands and Private Lands

The Plan's adoption altered the role that federal and private lands played in providing a broad array of environmental services and goods expected by the public. Adopting the Plan for federal lands was assumed to reduce pressure for stringent regulations for habitat conservation on private timberlands. In many senses, this assumption was correct, and the experience in the Pacific Northwest demonstrates how ecosystem management approaches can be operationalized. The experience has also demonstrated the role of federal (or public) timberlands in the context of all timberlands, in providing the array of environmental services and goods the public expects.

A wide diversity of ownerships characterizes the west side of the Pacific Northwest (table 5-2). Unlike most other regions in the United States, forest ownerships in the Pacific Northwest tend to be made up of large and relatively contiguous blocks of timberland leading to an interest in landscape-scale management approaches. The wide diversity of ownerships, public and private, has led to a patchwork mosaic of management regimes spread across the landscape. The variety of management regimes stems in part from differences in individual landowner objectives, market conditions, biophysical productivity, and regulatory conditions within different parts of the region (see Haynes and others 2003 for a summary of management regimes by owner).

The importance of considering the potential of forests to produce a broad array of environmental services and goods has evolved, and many of these services and goods are thought to be directly related to structural condition. The Pacific Northwest timberland base is structurally diverse and thought to be capable of producing a wide

Table 5-2—Forest land area in the United States Pacific Northwest west side, 1997

Land class	Total	National forest	Other public	Forest industry	Nonindustrial private
			Million acres		
Nonreserved					
timberland	23.297	7.134	4.572	6.837	4.755
Other	.692	.040	.173	.122	.357
Reserved	3.281	1.738	1.539	—	.004
Nonwilderness		(.174)	—	—	—
Wilderness		(1.564)	—	—	—
Total forest land	27.270	8.912	6.283	6.960	5.115

— = No acres assigned to these land classes. Totals may not add because of rounding.

Judy Mikowski

Forests provide a variety of products including trailing blackberries, here being collected for personal use.

array of environmental services and goods. Looking broadly, about half of the timberland base is less than 40 years old and half is more than 40 years old with 30 percent older than 80 years (these data are not available for the other public ownership class that includes the BLM) (Zhou and others 2005). The complementary nature of resource conditions and the contributions of various landowners are shown in figure 5-3, which illustrates the relative propensity of private timberland owners to provide early- and mid-seral conditions whereas older stands are in the national forests. Data at this resolution mask concerns about the spatial juxtaposition of different seral stages, but some of these concerns lack scientific rigor in their specification. The patchwork mosaic of management regimes (resulting from the diversity of land ownership objectives) spread across the landscape adds complexity to the various seral stages so that any stage is composed of relatively uniform to highly fragmented stands.

The implication of a broader look at forest land conditions is that the federal lands by themselves may not meet the goals of habitat conservation or the Montréal Process for sustainable forest management. All forest lands make a contribution toward achieving these broader societal goals. The Plan was an attempt to manage risks to late-successional and old-growth-related species and to prevent further listings that might affect private and other public timberlands; in that sense the Plan succeeded.

The Timber Industry Would Survive

The timber industry was assumed to survive under the Plan and to adapt to changes in federal harvest flows. In general, it has, although with some painful adjustments. Changes in the global forest products industry have helped mitigate some of the effects ascribed to the decline of federal harvest in the Plan area. The harvest decline in the Pacific Northwest (roughly 5 billion board feet) was offset by a combination of factors including harvest increases on private timberlands, increases in harvest in other regions particularly the U.S. South and the interior Canadian

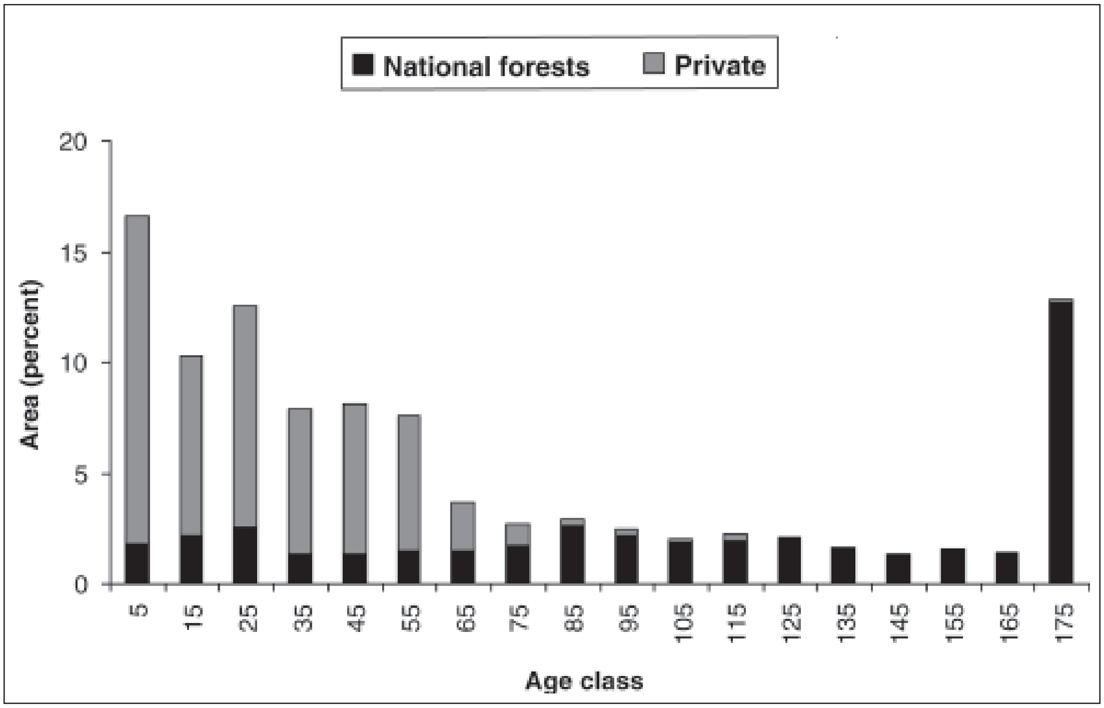

Figure 5-3—Age class distribution by ownership for softwood forest types on timberland area for the Douglas-fir region (western Oregon and Washington) for 2000. Source: Haynes and others 2003.

Provinces.[10] In addition, the collapse of the log export market from the Pacific Northwest (log exports deceased during the 1990s by more than 2 billion board feet, log scale) and the loss of other export markets helped mitigate the effects (see Haynes 2003 for a general discussion).

Improving inventory conditions in the U.S. South and the loss of Pacific Rim export markets all contributed to higher domestic production, mitigating any effects on consumers. These effects were always considered relatively small (estimated at $13 per household, FEMAT 1993). The U.S. total roundwood consumption increased by 4.5 percent during the past decade (11.6 percent for softwoods and -8.2 percent for hardwoods [Howard 2003]).

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Growing use of softwood lumber in residential construction challenges producers to meet market demands while using environmentally responsible practices that ensure the future of forests (this lumber carries the SFI [sustainable forestry initiative] logo).

[10] These shifts validated the warnings of those who said that federal protection for the spotted owl would shift the environmental consequences elsewhere. Economists call these types of effects "unintended consequences" and often argue that they demonstate policy failures in the sense of not having considered the full range of possible effects.

In the United States, a transition is underway where, after 2015, most softwood timber will be harvested from managed stands (see the discussion on pages 121-123 in Haynes 2003). Most of these managed stands are on private timberlands, mostly in the U.S. South and in the Douglas-fir region (west side of the Pacific Northwest). In part, this transition from harvesting in natural stands to harvesting in managed stands has mitigated some of the harvest reductions on public lands. The transition will further reduce the role that federal timber plays in the U.S. forest situation.

The timber industry in the Douglas-fir region restructured during the 1990s, evolving into a highly efficient but less product-diverse industry, focusing on lumber production primarily for the domestic market and using timber from private timberlands (see Barbour and others 2003, Haynes and Fight 2004). As such, it focuses on 14- to 20-inch logs. Currently, there is little capacity capable of handling logs over 24 inches in diameter. An evolving small-log industry uses logs between 4.5 and 10 inches small-end diameter. Mills themselves are changing with the development of both very large mills (producing 300,000 to 400,000 board feet per shift) and specialty mills, some of which are relatively small (less than 50,000 board feet per shift).

It is still a large industry operating at a vast scale. In 2002, 13.44 billion board feet of lumber was produced in Washington, Oregon, and California. This rate of production required 1.68 billion cubic feet of logs or 1.4 million truckloads. The basic data for both the industry and example mill sizes are shown in table 5-3. The industry has developed in an integrated fashion to use both roundwood and residues (45 percent of each log ends up as mill residues). Until the early 1990s, the industry in the three states relied on federal timber for roughly 38 percent of their logs.[11] These logs came from federal timber sales that were sold by using a mix of oral and sealed bidding. The FS sold on a scale basis, and the BLM mostly sold on a lump scale basis. Timber sales were appraised to various end markets, mostly sawtimber, and included the value of residue products.

During the past decade, many of the mills have moved. In the past they were dispersed across the region, and those depending on federal timber were generally less than 50 miles from where they bought timber. In the past decade, the surviving mills (and new mills) have located along main transportation corridors and close to the private timberlands where they procure timber. Now some rural areas, although timber dependent, have little local forest products manufacturing, and logs harvested in the area are shipped to manufacturing centers farther away (resulting in slightly lower stumpage prices than in the past) and reduced employment in spite of relatively high harvests.

The recent changes in the forest products industry have left some land managers wondering if local timber industry infrastructure can be maintained or reestablished where it has closed during the last decade. To help frame this issue, table 5-3 illustrates how much wood (logs) is needed to sustain three typical types of mills in western Oregon and Washington. A medium-size mill would need 16 truckloads of logs for each shift on each operating day. The production at this mill would generate enough chips to fill 13 chip vans every 2 days, which would need to be disposed of to residue-based manufacturing. In western Washington and northern Oregon, a pulp and paper industry is supported almost entirely from these residues. In the eastern and southern extremes of the northern spotted owl region, however, these residue-based industries are less available, which means that timber sales will depend on their sawlog components to be sellable because disposing of chips would be costly. The challenge to land managers is sustaining forest operations that can provide the magnitudes of log flows illustrated in table 5-3.

[11] After the adoption of the Plan, this proportion dropped to 15 percent.

Table 5-3—Wood requirements for one small, one medium, and one large sawmill and for the total industry, 2002

	Units of measure	Small sawmill	Medium sawmill	Large sawmill	Total industry
Production/shift	Thousand board feet, lumber scale	50	150	400	
Annual 1 shift production[a]	Million board feet, lumber scale	12.5	37.5	100	13,436
Chip, sawdust production[b]	Million cubic feet	.7	2.1	5.6	755.8
Annual log requirements[c]	Million board feet, log scale	6.25	18.75	50	6,718
Annual log requirements[d]	Million cubic feet	1.56	4.67	12.5	1,679.5
Log truckloads[e] per year		1,302	3,906	10,417	1,399,583
Chip vans per year[f]		549	1,648	4,394	590,449

[a] Annual production is computed assuming 250 operating days.
[b] Chip production computed as 45 percent of log input volume (in cubic feet).
[c] Computed assuming an overrun of 2 (there are 2 board feet of lumber scale for every board foot of log scale [Scribner scale]).
[d] Cubic volume computed assuming 4 board feet (log scale) per cubic foot.
[e] Computed assuming 1,200 cubic feet of logs per truckload.
[f] Computed assuming 16 units per truckload and there are 2.5 cubic feet of pulp chips per cubic foot of solid wood.

Changing Societal Values and Definitions of Old Growth

The Plan's adoption implied some consensus in societal values. The evolution of the debate over old growth illustrates how tentative this assumption has proven to be.

The term "old growth" has sparked debate ever since scientists began to modify the timber-inventory-based definitions in the early 1980s. The divergent perspectives on old growth reflect differences that stem from differing social perspectives and political agendas. Old growth became a household word in the 1990s during the northern spotted owl debates, which captured the attention of Americans across the country. At opposite ends of the spectrum are forest managers and environmentalists. Some environmentalists may view old-growth as pristine wilderness and ancient forests that are home to precious and endangered species and that have spiritual values. Some forest managers see old-growth forests as valuable timber that may be wasted.

Increased knowledge about Pacific Northwest forests has produced more definitions of old growth. Some scientists have indexed forest structural conditions along a continuum, rather than pigeonholing forests into simple categories of old growth or not. These scientists prefer a multifeatured approach to locating stands on a continuum of structural and compositional complexity and diversity. These definitions differ in the age assigned to old-growth stands as well as in the use of ecosystem processes and forest structure and composition to describe old-growth.

In 1986, the FS Old-Growth Definition Task Group described Douglas-fir old-growth forests as those with two or more tree species with a wide range of ages and tree sizes; six to eight Douglas-fir or other coniferous trees per acre at least 30 inches in diameter or at least 200 years old; a multi-layered forest canopy; two to four snags per acre at least 20 inches in diameter and at least 15 feet tall; at least 10 tons per acre of fallen logs, including some at least 24 inches in diameter and 50 feet long (Old-Growth Definition Task Group 1986).

FEMAT (1993) and the Northwest Forest Plan FSEIS (USDA and USDI 1994a) used a different definition: old-growth forest stands are usually at least 180 to 220 years old with moderate-to-high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; high incidence of large trees, some with broken tops and other indicators of old and decaying wood; numerous large snags; and heavy accumulations of wood, including large logs on the ground.

In 2000, the National Research Council's Committee on Environmental Issues (2000: 45) in Pacific Northwest Forest Management defines old-growth forests as those that support assemblages of plants and animals, environmental conditions, and ecological processes not found in younger (less than 100 to 250 years, depending on species) forests.

In current political debates, old growth in the Douglas-fir region is being defined as forests of natural origin older than 120 years and trees larger than 21 inches in diameter. These definitions are likely to be legislated in forthcoming laws and regulations. Little scientific basis exists for such laws, but they reflect current societal values about cutting green timber on federal lands. The laws also represent a diminishing role of scientists in contributing to these definitions.

Governance of Forest Management Would Change

The Plan recognizes how the changing public appreciation of the array of services and goods provided by forests calls for a different way to govern forest management actions. In this context, governance is defined as exercising authority over actions, and it has evolved in the Pacific Northwest from being market based to being a mix of market and regulatory functions (see Haynes and others 2003 for an expanded discussion). For federal forest lands, forest planning has been developed to implement forest management. It includes formal processes, broad management objectives, and increased stakeholder participation. Management on private forest lands is determined by a mix of market and regulatory functions. Different regulations (for example, state forest practice acts) influence both the design and applications of forest management practices.

For the most part, these regulations reflect a manifestation of public concerns about forest lands or forest conditions. These growing public concerns have long been a determinant of forest policies, and since the early 1990s, forest policy has increasingly been internationalized (see the discussion on pages 173-179 in Haynes 2003) in the context of both economic globalization and sustainable development. Currently, much of the international debate deals with different suggestions about the need to supplement market-determined actions with processes that try to find an equilibrium among interests advocating environmental protection, employment that contributes to economic prosperity, public access, and social justice (see Andersson and others 2004 for a variety of perspectives on these issues).

The Plan's adoption for federal lands is a unique step in this evolution of shifting societal expectations for forest management. It takes an interagency approach and includes developing different institutions to supplement the existing mix of market and regulatory processes already present in the region. These institutions included a mix of formal and informal groups and organizations. Among the federal land management and regulatory agencies, the Regional Interagency Executive Committee (RIEC) and the REO were established to oversee the implementation of the Plan. The role of the RIEC has expanded to provide a forum for discussing emerging problems beyond just implementing the Plan.

At the same time, implementing the Plan included developing several collaborative efforts whose success rested on involving both formal and informal groups. For example, the success of the adaptive management areas (AMAs) depended on developing an interchange among stakeholder (and local community) groups around specific land management actions in a specific place (see Charnley and others 2006b; Stankey and others 2003b). For the most part, developing effective collaboration was difficult because sufficient experimentation on the AMAs was lacking and little attention was paid to stakeholder engagement. Where successes were found, they depended on early engagement of stakeholders in the assessment part of planning and on fully involving them with the goal of gaining social acceptability for designed treatments. In some selected cases, engagement with informal groups led to partnerships that were able to accomplish specific actions collaboratively.

Another institution that was established in the ROD (USDA and USDI 1994b) was the provincial advisory committees that provided opportunities for coordination and information exchange at the province scale. The successes of these as effective institutions were mixed, but they have provided an opportunity to engage other less formal organizations such as watershed councils. In 2000, resource advisory committees (RACs) were established; these are more formal organizations in both how they are composed and how they function. The RACs are being effective in shaping ecosystem management decisions given their role in recommending (under Title II of the 2000 Secure Rural Schools and Community Self-Determination Act) road maintenance, watershed restoration, and hazardous fuels reduction projects. These organizations have been less successful in contributing to governance processes that influence all forest lands in the region.

Although not a formal institution, but one that has played a key role, stumpage markets during the 1990s have been highly volatile as landowners and forest products producers have adjusted to the reductions in federal timber flows (see Warren 2004, for various data series, and Haynes 2003 for a discussion of regional and national markets adjustments). Since the mid-1990s, stumpage prices have been either declining or stable, suggesting lower financial returns to various forestry practices. These lower prices may lead the many landowners, each with their own objectives, to respond in ways not supportive of sustainable forest management. As this happens, advocates for improved forest management (like the RIEC and the regulatory agencies) may find themselves supporting more regulation to ensure progress toward sustainable forest management across a broader number of forest land acres.

The Plan is one of the few experiments in developing an overarching framework for governing forest land management. It offers several lessons about how to develop alternative governance approaches than just depending on an uncoordinated mix of market and regulatory approaches. As societal expectations evolve for maintaining sustainable forest lands, overarching institutions like a RIEC and REO and others that may be developed can respond to and coordinate legal frameworks, decisionmaking processes, landowner objectives, and forest and land-use policies. The experience in the Pacific Northwest suggests that developing these overarching institutions will be difficult given the diversity in landowner objectives, the propensity for rapid changes in societal values, and the difficulty of power sharing in a pluralistic society.

Treatment of Uncertainty

The original design of FEMAT did not address human prospectives of uncertainty and risk. From the past decade we now have a better understanding that these involve risk perceptions and attitudes (see Haynes and Cleaves 1999). Often, the public does not perceive risks in the same way that scientists or managers describe risks. The public often treats risks and uncertainy in a generic fashion where scientists tend to separate risks from uncertainty trying to predict the likelihood of some events with mathematical precision. For example, fire risks in the interior Columbia Basin can be computed as 1 percent per year (average number of acres burned per year divided by the number of forest land acres). Other events are too uncertain to reduce to a mathematical expression. Making decisions in these two cases takes different approaches, but it also depends on the attitudes of decisionmakers toward risk. The human aspect of assessing uncertainties is how individuals express their risk attitudes; that is, the extent to which an individual seeks or avoids risks. For example, surveys of forest supervisors show them to be risk averse (Kennedy and others 2005). In risky situations they tend to choose the least risky direction. For example, in fighting a fire they are likely to overreact (adding resources) to increase the likelihood that the fire is controlled.

Finally, there has been some evolution in thinking about the tradeoffs of ambiguous gains in environmental conditions for nearly certain economic losses. The increased discussions during the 1990s stimulated largely by concerns around sustainable development have led to a greater appreciation that managing ecosystems involves managing a set of common property goods and services. This raises two issues. First are the traditional economic arguments about how common property is abused rather than protected. Second, the champions of civic society argue for greater attention for common goods.

In this context, the Plan emphasizes viewing forest management decisions as involving broader environmental problems dealing with complex tradeoffs (or compatibility) among a broad set of environmental values including timber, wildlife habitat, aesthetics, biological diversity, water flows, ecological integrity, and recreation. As such, it considers ecosystems as a set of commons whose goods and services are fairly available to anyone. Hardin (1968) laid out the common property issues involved in management in his classic article "The Tragedy of the Commons." The essence of his argument was that if no one held property right to various goods and services, then there was no incentive to manage the resource to sustain production but rather to capture as much of the value as quickly as possible before others seized the various goods and services.

Reductions in federal harvests led to the closure of modern mills like the Stevenson, Washington, co-op plywood mill with the attendant loss of jobs and personal wealth.

In addition to the economic implications, there is also a role for governance in assigning property rights to sustain various environmental services and goods. Here advocates for the role of civic society have pushed agendas that essentially attempt to assign property rights to various stakeholder groups who have traditionally been marginalized in market-based approaches to resource allocation and management. The Plan is an example of habitat and old-growth values being assigned greater worth than production forestry values.

Considerations

The political compromise leading to the Plan linked timber production on federal lands with jobs and community well-being. Since implementing the Plan, the debate has been generalized to imply that increased environmental protection threatens jobs and, therefore, community well-being. These issues framed the socioeconomic monitoring questions derived in part from President Clinton's five principles.

The socioeconomic monitoring effort associated with the implementation of the Plan was an enormous accomplishment. For the first time, we have information about the effectiveness of a broad-scale forest management decision in terms of the key underlying questions. In general, the Plan enabled federal agencies to resume timber harvests. In terms of output, timber sale expectations were not met and there was a mix of effects on grazing and mineral activities and for recreation opportunities. Comminities changed across the region, and although it is difficult to disentangle changes caused by the Plan from other changes, there are still individuals who express a sense of lost social and economic opportunities. The mitigation activities that attempted to minimize adverse impacts on economic well-being by assisting with economic development and diversification opportunities had generally positive effects.

The overall growth in regional economies reduced many of the effects of reductions in federal timber flows. But attempts in the economic adjustment initiative to provide displaced workers with alternative forest-based jobs were less successful than expected (this experience is similar to that in the Redwood Park experience [see Deforest 1999]).

The Plan engendered a new discussion among forest management advocates about what broad environmental values should be protected for future generations. These include protecting old-growth-related species and many of the uses and values important to urban people. The monitoring showed that the uses and values that rural people associate with forests were not protected to the same extent. The Plan did engender considerable new collaboration between and among the federal agencies and public engagement in new forums.

This last decade has seen a broadening of societal concerns about forest management. Concerns used to focus on species conservation; now the emphasis is on achieving sustainable forest management across all forest lands. Social acceptance of forest management activites has also shifted, suggesting the importance of building and maintaining trust with citizens. Concern about community dependency has shifted to concern about community adaptability. The Plan has also demonstrated the importance of strengthening governance when implementing broad-scale forest management.

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Chapter 6: Maintaining Old-Growth Forests

Thomas A. Spies

Introduction

The Forest Ecosystem Management Assessment Team (FEMAT 1993) was directed to develop alternatives that met this objective, among others:

> Maintenance and/or creation of a connected or interactive old-growth forest ecosystem on the federal land within the region under consideration.

The FEMAT produced several alternatives, one of which, option 9, was selected by the President as the basis of the Northwest Forest Plan (the Plan), described in the Record of Decision (ROD) (USDA and USDI 1994). To a large degree, the success of the Plan depended on the structure, composition, and dynamics of forest vegetation. In this chapter, I describe the general and specific expectations of the Plan, what has happened, and what we have learned from monitoring. Critical Plan assumptions are reviewed in the context of recent science findings and new perspectives, and alternative approaches to meeting the Plan's goals are discussed.

The terminology associated with the concept of old growth is often confusing. Other terms associated with old-growth forests have included mature forest, old forest, older forest, and late-successional. In this chapter, "mature" forests refer to the stage of stand development that occurs just prior to the old-growth stage (figs. 6-1, 6-2), "older" forest encompasses both mature and old-growth stages and is the term used in the status and trends report (Moeur and others 2005) for the general set of different inventory definitions. "Late-successional" has also been used in FEMAT and the ROD for these later two stages of stand development, but its usage in the Plan is somewhat confusing. In this chapter, I will use "older" forest as it was used in the status and trend report. Some authors will use the term "old forests" as a substitute for "old growth" if they consider that term too limited (for example, only forests with massive old trees) or too value laden. I will use "old growth" to refer to the last stage of stand development that is typically associated with stands with large old trees and complex structure (figs. 6-3 through 6-6). I present a more indepth discussion of definitions and the ecological concepts of forest development later in the chapter.

What Was Expected?

The assessment of the state of old-growth forests was based on the assumption and observations (Bolsinger and Waddell 1993) that amounts of old-growth forest had steeply declined during the 20th century, placing associated species at risk and reducing the contribution of old-growth forests to ecosystem functions such as carbon storage and the hydrologic cycle. The obvious correction for this problem was to develop management policies that reduced the rate of loss of existing old-growth forests and at the same time promoted the growth of new areas of older forest. Because the problem is rooted in the loss of old-growth forest, relative to past amounts, the solutions under the Plan were based on returning the federal landscape toward an extent of old-growth forest more in line with what was here before widespread logging on federal lands. The historical extent was assumed to be adequate to sustain the native biological diversity associated with older forest. To do this, the amount of the historical landscape covered by older forest in the past had to be estimated. The answer to this question, however, was not as simple as determining how much older forest occurred at some past point or period in time, such as the early 1800s before Euro-American settlement. Forests are dynamic as a result of disturbance, growth, and succession; consequently, the abundance of older forest varies over time—no single point or short period can realistically be used to characterize this dynamic system. Under the historical natural disturbance regime (type, severity, and frequency of disturbance), the amount of

Expectations for the Old-Growth Network in Fire-Prone Landscapes

The old-growth reserve network was established under the assumption that some areas of old forest would be lost to stand-replacement disturbances including wildfire. Given the forest types, environments, and disturbance history of the Plan area, this assumption is entirely warranted. It is not realistic to assume that fire suppression will stop wildfires—the monitoring results demonstrate this—and it is not desirable to stop all fires in these landscapes given their importance to the functioning of these ecosystems. For example, old growth in ponderosa pine and dry mixed-conifer types is maintained by frequent low-severity wildfire and patchy disturbances from insects and disease (Spies and others 2006). The Plan did not explicitly evaluate how changes in fire regimes resulting from fire exclusion might affect the amount and dynamics of old growth in dry provinces, however, and it did not state expectations for forest dynamics in these areas.

A key part of the monitoring strategy was the development of expected trends in key indicators. For example, the total amount of older forest was expected to increase at a mean annual rate of 1.2 percent (FEMAT 1993 fig. IV-2) despite losses to high-severity wildfire, which were projected at an annual rate of 0.25 percent for the Plan area. The actual rates of net increase (1.9 percent) were higher and the rates of loss (0.18 percent) were lower than expected—deviations that are consistent with old-growth goals of the Plan. The establishment of expected trends was necessary to provide a context for evaluating the significance of the changes that do occur. Given the uncertainties and variability of disturbance regimes and forest development, the expected trends should be viewed largely as educated guesses based on historical dynamics and our general understanding of forest growth and disturbance.

Although the overall rates of loss of older forest to high-severity fire were lower than expected, some of the dry provinces had much higher rates than the average. For example, the Oregon Klamath province had a decadal rate of loss of about 9.5 percent, compared to the regionwide average of 1.8 percent. If we assume that this percentage loss was similar for the province as a whole (not just the older forest part), then the high-severity fire rotation would be about 105 years. Assuming a stochastic pattern of burning and a negative exponential model (Agee 1993), this would create a landscape that on average had about 15 percent of the area in forest with large pines and Douglas-firs over 200 years of age. The Eastern Cascades province in Oregon had a relatively low rate of loss up to 2002, the end of the measurement period. However, if 2003, the year of the B and B Fire, were included, an additional 25,000 acres of older forest would have been burned, and the decadal rate of loss would have increased to 14.6 percent (a high-severity fire rotation of 69 years). If this rate of disturbance were sustained, then the percentage of forest with old trees would be around 5 percent on average. Clearly, these outcomes would not be desirable because the area of dense mixed-conifer old growth, which was subject to mixed-severity fire, and open pine old growth, which was maintained by frequent low-severity fire, would decline.

This simple analysis only tells part of the story because it does not take into account other disturbances from insects and disease and the cascading effects of increased high-severity fire. Losses of old trees to insects and disease would continue to occur and further reduce the amount of older forest and trees in these landscapes (Spies and others 2006). Increased occurrence of high-severity fires could lead to stands and landscapes with a more uniform structure (either shrubby fields or areas of dense regeneration) than could have occurred under the low- to mixed-severity fire regime. This uniformity would create a positive feedback loop that further increases high-severity fire and insect and disease outbreaks. Although some uniform patches of early-successional forest would have occurred and contributed to biological diversity, large areas of such stands would be less desirable for the goals of the Plan, which emphasize retaining structurally complex stands including large live trees. Within ponderosa pine and dry mixed-conifer types, large patches of early-successional forest are thought to have been historically rare, although Hessburg and others (2005) argued that high-severity fire in dry mixed-conifer forests was more common than previously thought.

The FEMAT recognized that the desired outcomes of the Plan had a lower chance of success in the dry provinces; however, the situation may be worse than expected. The assessment of option 9 (the selected option) assumed that the fuel reduction treatments would be sufficient to lower the risk of high-severity fire. The lack of fuel treatments in and around late-successional reserves probably has decreased the likelihood of success of the Plan. Furthermore, recent models of climate change effects project some of the greatest changes to occur in the driest parts of the Plan area.

A reassessment of current and potential future landscape patterns and dynamics at the province level would be beneficial. A reassessment would provide managers and the public with a clearer set of expectations for provinces and large landscapes. Many are confused at present about what to expect from the Plan in dry provinces and how management practices should differ across the diverse environments of the Plan area. It would also provide guidance for actions to reduce risks of loss of older forest to natural disturbances and clarify the tradeoffs associated with different management approaches for these dynamic landscapes.

Tom Spies

Figure 6-1—One-hundred-forty-year-old mature Douglas-fir stand in the western Oregon Cascade Range.

Tom Spies

Figure 6-2—Ninety-year-old mature Douglas-fir stand in the western Washington Cacade Range.

Tom Spies

Figure 6-3—Old-growth Douglas-fir, western hemlock forest in the Western Oregon Cascade Range.

Tom Spies

Figure 6-4—Old-growth Douglas-fir and western hemlock stand illustrating tall, deep canopies in the western Cascade Range of Oregon.

Tom Spies

Figure 6-5—Open old-growth ponderosa pine with a history of surface fires at Pringle Falls Experimental Forest in the eastern Cascades of Oregon.

Tom Spies

Figure 6-6—Dense old-growth ponderosa pine stand without history of recent low-severity fire at Pringle Falls Experimental Forest in the eastern Cascades of Oregon.

particular young and old forest stages can vary from 0 to 100 percent of a small landscape or watershed. At larger spatial scales, the amounts of different seral stages typically have a more restricted range of proportions because most disturbances do not cover entire provinces or regions (Wimberly and others 2000). For example, the amount of old-growth forest in coastal Oregon was estimated to range between about 35 and 75 percent of the province under the historical fire regime (Wimberly and others 2000). This range is termed the historical range of variation (HRV) (Landres and others 1999). This reference to historical disturbance regimes was used in characterizing the potential outcomes of the options considered in FEMAT (1993: IV-49 to IV-51).

The expert panel assessments in FEMAT were based on outcomes for older forest described in terms of historical abundance and diversity, ecological processes, and spatial pattern or connectivity under the historical disturbance regimes of the region. For example, the outcomes for abundance and diversity were described as (1) at least as high as the long-term average amount of late-successional forest, (2) below the long-term average but within the historical range that would be expected under past disturbance regimes, (3) considerably below the low end of the historical range of conditions, and (4) very low in abundance and may be restricted to just a few provinces or elevations within a province (FEMAT 1993: IV-49 to IV-53). The panels characterized the options by the likelihood that the policy option would lead to the outcomes described above. This characterization was done separately for the moist provinces, where fire frequencies were relatively low, and for the dry provinces, where fire frequencies were relatively high. For the moist provinces, the panels estimated a 77 percent likelihood of achieving outcome 2 under option 9; for dry provinces, this likelihood dropped to 63 percent.

The assessments (FEMAT 1993) set the general expectations and context for older forests under the Plan: it will probably lead to an outcome in which the abundance and ecological characteristics of late-successional forest at the scale of the Plan area fall within the range of what might have occurred under the historical disturbance regimes of the past; significant uncertainty exists about outcomes over the lifetime of the Plan; the uncertainty in outcomes is especially high in dry provinces, where decades of fire suppression makes it difficult to achieve outcomes based on disturbance regimes of the past.

What Are the Status and Trends and What Differences Were Found Between Expectations and Observations From Effectiveness Monitoring?

The older forest status and trend report (Moeur and others 2005) provides a wealth of information over the Plan's first 10 years. That report may be the most comprehensive monitoring of old-growth conditions that has ever been written. Despite the richness of the data sets, the monitoring timeframe is only 1/10 of the 100-year timeframe of the Plan, 1/20 of a 200-year return interval between lethal fires typical in some areas, and only 1/100 of the potential maximum age of a Douglas-fir tree (see appendix for scientific names). Consequently, these trends should be viewed with caution because they could be quite different in the next 10-year period.

The specific outcomes and expectations for older forest under the Plan can be divided into three major areas: abundance and diversity; process and functions; and connectivity.

Abundance and diversity—

Most of the findings from the status and trend report (Moeur and others 2005) are related to the abundance and diversity of older forest, where "older forest" is the term used to refer to mature and old-growth stands. The following findings are especially significant:

- The estimate of the amount of older forest depends on which structural definition is used—adding more structural criteria to the definition would reduce the area of forest that meets a definition because not all older forest stands possess all of the structural features associated with the general population of older forests.
- The area of older forest (as defined by medium- and large-diameter trees [>20 inches and 29.5 inches in diameter, respectively] with simple or complex canopies) on federal lands estimated from remote sensing at the Plan's beginning was within 10 percent of the value estimated in the recent monitoring analysis, which was based on improved remote sensing models and inventory plots.
- The Plan assumed that most of the remaining older forest in the Plan area was on federal land. Although some provinces have some significant areas of mature forest (medium- and large-diameter trees) on nonfederal lands, nearly 80 percent of the largest and most structurally complex class occurs on federal land. This assumption is supported by the new inventory information (table 6-1), which confirms estimates of earlier inventories (Haynes 1986, SAF 1984).
- Thirty-four percent of the federal land base was covered by older forest with medium to large trees and simple to complex canopies. Older forest with very large trees and complex canopies covers about 12 percent of the federal land base and is concentrated in forests west of the Cascade divide.
- The reserve system captured the most structurally complex portion of the remaining older forest; for example, the proportion of large multistoried old forest in reserves was nearly twice as high as in matrix lands.

Table 6-1—Area and percentage of older forest on federal and nonfederal[a] land

	Federal		Nonfederal		Federal land	
Province	**ML**	**LMS**	**ML**	**LMS**	**ML**	**LMS**
	– – – – – – – – – – – *Acres* – – – – – – – – – – –				– – *Percent* – –	
California Cascades	356,778	24,656	320,507	26,035	52.7	48.6
California Coast	167,582	75,017	1,425,813	240,719	10.5	23.8
California Klamath	1,833,569	385,706	321,383	25,400	85.1	93.8
Oregon Coast	522,962	295,504	727,137	268,009	41.8	52.4
Oregon eastern Cascades	222,787	26,654	94,522	5,120	70.2	83.9
Oregon Klamath	719,296	384,597	233,374	86,557	75.5	81.6
Oregon western Cascades	1,909,647	733,603	268,008	60,476	87.7	92.4
Oregon Willamette Valley	4,644	0	194,992	0	2.3	0.0
Washington eastern Cascades	164,336	0	82,097	0	66.7	0.0
Washington Olympic Peninsula	612,770	284,444	140,968	28,485	81.3	90.9
Washington western Cascades	1,353,454	512,275	308,726	72,159	81.4	87.7
Washington Lowlands	108	0	256,755	0	0	0
Plan area	7,867,932	2,722,454	4,374,287	812,958	64.3	77.0

Note: Totals may not add because of rounding.

ML = medium and large conifers; LMS = large multistoried conifers.

[a] The area on nonfederal land was estimated by using a geographic information system with remote sensing vegetation layers of Moeur and others (2005) and a layer of federal and nonfederal forest land in the Plan area.

- Losses to older forest from stand-replacement natural disturbances, such as fire, were actually less than what was expected for the Plan area (0.18 percent annually vs. expected 0.25 percent) (FEMAT 1993) as a whole. However, within several of the dry provinces, rates of loss of older forest to wildfire were much higher than the overall average, and these provinces accounted for most of the losses to high-severity wildfire.
- The average net increase in older forest with a quadradic mean diameter (qmd) of >20 inches (1.9 percent average annual increase in the area of old forest) since the Plan began was higher than the 1.2 percent annual net increase expected in the ROD (the ROD estimate did not include California).[1] Some of this higher rate of increase was because much less old forest was cut in the matrix than the Plan originally called for (Baker and others, in press). This lack of logging, however, accounts for only about half of the higher net rate of increase. If logging of old forest in the matrix had occurred at the expected rate of 800 million board feet per year, I estimate that the net rate of increase of older

[1] The net annual increase of 2.2 percent in stands with a quadratic mean diameter (qmd) of at least 20 inches probably results largely from growth and development of natural stands with qmd greater than 17.7 inches in the 1990s. Natural Douglas-fir stands of this diameter would probably be 80 to 100 years old, assuming site class III (McArdle and others 1961). The immediate effects of thinning on the size distribution of plantations, and thus on qmd, might account for some of this increase, but most plantations on federal land were less than 40 years old in the mid-1990s and would be expected to have qmd of less than 13.8 inches at that time. Thinning from below to remove smaller diameter classes would not change stand structure enough to increase qmd beyond 20 inches, in most cases.

forest would have been reduced by about 19,000 acres/yr or about 0.3 percent per year. (This assumes a volume removal of about 42,000 board feet/acre).

- Rates of loss of older forest differed widely among provinces; annual rates of loss to high-severity fire ranged from 0.05 to 0.95 percent in dry provinces and 0.0 to 0.14 percent in wet provinces (table 6-2).
- Fifty-five percent of the area of older forest types occurred in climatic zones and vegetation types, in which relatively frequent low-severity fire or thinning is needed to maintain desired old-forest structures and to reduce the probability of high-severity fire (table 18 in Moeur and others 2005).

The status and trend results for abundance and diversity should be viewed with several cautions. First, the remote sensing and inventory plot data are not a complete picture of the ecological characteristics of the older forests of the region. Only broad classes of canopy size and canopy patchiness were used in inventories. Information about numbers of large trees, subcanopy trees, and large pieces of dead wood, for example, were not included. A more comprehensive analysis might reveal a different picture.

Second, the area lost to timber harvest logging (16,900 acres) and wildfire (102,500 acres) is probably underestimated because only disturbances larger than 5 acres were analyzed. In contrast, Courtney et al. (2004) in an owl status report estimated that almost 156,000 acres of owl habitat were lost to timber harvesting between 1994 and 2003. The status report estimate is almost certainly too high because it was based on timber harvest plans that were submitted by the USDA Forest Service (FS) and Bureau of Land Management (BLM) during consultation, and the agency does not typically update its database for what was actually implemented (Thraikill 2005). A large number of projects to harvest older forest in the matrix lands were not implemented because of legal challenges and other factors (Baker and others, in press). Furthermore, federal forest managers frequently submit plans that overestimate the area of owl habitat affected by project activities to give themselves flexibility in the implementation stage (Forrester 2005). Although the remote-sensing-based change analysis cannot detect very small patch disturbances, it has relatively high accuracy (88 percent) for small to large stand-replacement disturbances (Cohen and others 2002). Because most timber harvesting plans in older forest in matrix lands would use cutting units larger than 5 acres, the change analysis probably does not underestimate loss by a large factor.

Third, the net changes in older forest come largely from the gradual growth of the diameter of stands into the lower end of the 20-inch diameter class and not much from the development of old-growth forest with very large trees and complex structure. The relative high percentage increase comes in part because of a bulge in the size-class distribution of forests with diameters just below the 20-inch class. After this bulge moves into the >20-inch class, rates of increase in this forest size class will decline. Given the limitations of the change analysis, we do not know the actual net changes in old-growth forest that occur from losses to fire and timber harvest and increases from the development of mature forests into old-growth forest.

Processes and functions—
The effectiveness monitoring program was not designed to provide information about the status and trend in the processes and functions of older forest. Processes refer to ecological dynamics that lead to development and maintenance of old-growth forests. For example, rates of succession, gap formation, low-severity fire, productivity, decomposition, and so on are all important to the development of old-growth forest. Some process trends can be inferred, however. For example, the amount of low-severity fire in old forest in dry provinces is probably not enough to sustain old forests (for example, Ponderosa pine) that depend on fires with frequencies of less than 35 years (Agee 1993). Little data were available to support this hypothesis, but if historical rates had occurred, fires would have been widespread throughout the forests in these provinces. Data from the implementation monitoring report (Baker and others, in press) suggest that the area of forests

Table 6-2—Area and percentage of old forest lost to wildfire, and mean fire frequency in years between 1994 and 2003[a] for the entire Plan area and by province

Province	LM[b]	Forest-capable area[b]	LM	Loss to fire	Period	Annual rate	Decade rate	Frequency
	Percent	*– – – – – – – – – – Acres – – – – – – – – – –*			*Years*	*– – – Percent – – –*		*Years*
Oregon Klamath	34	2,104,367	715,485	47,600	7	0.95	9.5	105
Washington Eastern Cascades	5	3,347,553	167,380	3,700	6	.37	3.7	271
California Klamath	43	4,221,438	1,815,202	29,900	9	.18	1.8	546
Oregon Western Cascades	44	4,379,051	1,935,208	18,700	7	.14	1.4	724
Oregon Eastern Cascades	15	1,477,506	221,626	800	7	.05	.5	>1000
California Cascades	36	999,795	359,926	500	9	.02	.2	>1000
Washington Western Cascades	38	3,516,105	1,336,120	300	6	0	0	>1000
California Coast	47	357,822	168,176	0	9	0	0	>1000
Washington Olympic Peninsula	43	1,419,276	610,289	0	6	0	0	>1000
Oregon Coast	37	1,396,232	516,606	0	7	0	0	>1000
Oregon Willamette Valley	25	18,521	4,630	0	7	0	0	>1000
Washington Lowlands	5	2,173	108	0	6	0	0	>1000
Plan area			7,850,758	101,500	7.2	.18	1.8	560

Based on (Moeur and others 2005).

[a] Periods differ by province: California 1994-2003; Oregon 1995-2002, Washington 1996-2002.

[b] LM = forests with large and medium-size conifers (>20 inches d.b.h.) as a percentage of forest-capable area.

treated to reduce understory fuels either through prescribed fire or mechanical means was not high. The rates of other processes such as gap formation, regeneration, and nitrogen fixation are not known. The effects of invasion by nonnative species on old-forest development are also unknown.

The functions of old forest are those ecological characteristics that are of value to other organisms or humans. For example, old-growth forest provides ecological legacies (for example, large live and dead trees) used by organisms in open and young forests that develop following stand-replacement disturbances (McIver and Starr 2000). This function is operating largely as it would have under a natural disturbance regime. This observation is based on the assumption that few acres of old forest killed by stand-replacement disturbances (more than 120,000 acres) were salvaged logged, which would have been the standard practice when timber production was a major goal on the federal lands. We know little about other potential functions of older forest such as production of clean water and nitrogen fixation.

Connectivity—

Connectivity in the Plan refers to the degree to which the spatial distribution of older forest provides for movement of plants and animals between old-forest patches. Connectivity can be measured in many different ways and does not necessarily mean that the patches of old forest need to be physically connected to each other. Most organisms can disperse across areas that are not prime habitat, but some are better dispersers than others. The FEMAT defined connectivity in terms of distance between areas of older forest and the portion of older forest in the landscape. The expected outcome for connectivity was that the distances between large blocks of late-successional forest would be less than 12 miles on average (FEMAT 1993: IV-52). The status of connectivity over the entire region depends on the definition of old forest and the process examined. Connectivity for the mature and old types together appears moderate to strong, based on the fact that the average distance between large blocks of this type was 6 miles for most provinces and that the proportion of the landscape in old forest is above 25 percent. When older forest was defined more restrictively, that is, large multistoried, then connectivity was less but still within 12 miles for most provinces, except the California coast.

Are the Plan's Assumptions and Approaches Still Valid?

The Plan was based on many assumptions about natural forest ecosystems, management effects, and forest dynamics. If these assumptions are no longer valid, it could mean that the Plan will not work as intended, that it might be modified to achieve its goals, or even that the goals should be changed. The assumptions could change for several reasons: first, the status and trend of old forest might not be what was expected; second, new scientific findings could emerge from work outside of the effectiveness monitoring program that would change the validity of underlying assumptions; third, new perspectives about forest ecosystems might have emerged from new interpretations of existing scientific information. In reality, our assumptions about ecosystem management plans often change as a result of both new research studies and new interpretations. The status and trend summarized in the previous section do appear to meet Plan expectations. In the following sections, I address new scientific findings and perspectives that might be relevant to the success of the Plan.

Old-Growth Forest Definitions

The Plan used the term "late-successional/old-growth" to describe the older forest conditions that were of concern. This term includes the mature and old-growth stages of stand development, where old growth is defined as a stand containing large live and dead trees, a variety of sizes of trees, and vertical and horizontal heterogeneity (figs. 6-3 through 6-6). The mature stage of development occurs as trees approach their maximum height and crown diameter but lack the heterogeneity of older forests (figs. 6-1 and 6-2). In Douglas-fir forests, the old-growth stage typically occurs at 150 to 250 years after a stand-replacement disturbance and can persist with slow changes for an additional 500 years or more (Franklin and others 2002). The mature stage typically begins around 80 to 120 years of age in Douglas-fir forests. These age ranges and degree of structural development may differ in other forest types in the region. The mature stage of stand development was considered in FEMAT along with old growth because it could develop into old-growth conditions within the lifetime of the Plan, it can be structurally and compositionally similar to old growth, and, in some areas, the most ecologically valuable large patches of uncut forest were in the mature stage of stand development. Many of today's mature forests will become the old-growth of the future and are needed to maintain old growth over time.

Use of the term "late-successional" to describe older forest has caused some confusion. It was really intended to refer to both the mature and old-growth stages of development, but it is frequently used as if it were a stage that is separate from old growth, that is, the mature stage. This usage is confusing because the mature stage of forest development is actually not as successionally advanced as old growth. The status and trend report of Moeur and others (2005) uses the term "older forest" to refer to the mature and old-growth stages. This term is simpler and more descriptive of the conditions of mature and old forests than is the term late-successional.

Another source of confusion stems from the two ways that plant ecologists conceptualize vegetation change over time following stand-replacement disturbance: succession and stand development (Frelich 2002). Succession typically refers to a directional change in species composition over time where one or more species replaces others. Generally the species that come later are more shade tolerant and are often referred to as late-successional species, because they can regenerate in canopy gaps and maintain themselves within closed-canopy forests in the absence of stand-replacement disturbance. Stand development refers to population/structure changes as forests age. Stand development may or may not be accompanied by a change in species composition. For example, fire in ponderosa pine forests may simply regenerate new populations of ponderosa pine but not change species composition. Consequently, it is possible to have old growth (an aging population of trees and associated structures) composed of early-successional species (for example, ponderosa pine, aspen) and old growth that is composed entirely of late-successional species (for example, western hemlock, or grand fir). One could distinguish early-successional old growth from late-successional old growth.

The ecological characterization (with the exception of the terminology) of older forest in the Plan is generally valid, but since then researchers have become aware that the diversity and complexity of natural forests is greater than some of our conceptual models have portrayed. Our general scientific model of older forest and forest dynamics in general has become more refined as a result of studies of old-growth structure in Douglas-fir and other forest types (Youngblood and others 2004), old-growth stand development (Ishii and Ford 2001, Poage and Tappeiner 2002, Tappeiner and others 1997, Winter and others 2002), disturbance history (Weisberg and Swanson 2003), and from new perspectives on forest complexity and stand development (Franklin and others 2002, Spies 2004). Collectively, these studies lead to several important observations about older forests, which are described in the next several paragraphs.

Old growth is part of a multivariate continuum of forest structure and composition, and breaking this continuum up into classes is arbitrary (Spies 2004, Spies and Franklin 1991). This continuum can be divided into classes in various ways, and a larger variety of classes may be needed to capture the diversity of types than has been used previously (Franklin and others 2002).

For Douglas-fir forests, old-growth characteristics typically begin to emerge at 150 to 250 years following stand-replacement disturbances. These characteristics include trees greater than 39.4 inches diameter at breast height (d.b.h.), associated lower and midstory shade-tolerant trees, large dead trees (>49 feet tall and 20 inches d.b.h.), large fallen tree boles on the forest floor, a diversity of heights of foliage, and patchy distribution of canopy gaps and understory vegetation. On high-productivity sites, some of these characteristics can begin to appear as early as 100 years. Where the initial disturbance was patchy, structures characteristic of older forest can emerge much earlier, sometimes as soon as 80 years depending on how much was killed in the initial disturbance. Age can be a rough approximation for old-growth stands in the northern and coastal provinces of the Plan area where disturbances are relatively large and kill most of the trees. Where disturbance regimes are characterized by patchy low- to moderate-severity fires, however, stand age is not a very useful measure of old-growth condition.

Old-growth structure and composition can change over time within a stand. For example, in the dry provinces, old-growth ponderosa pine can succeed to old-growth pine and fir.

Not all old-growth forests share all of the same attributes or have the same expression of structural complexity. For example, fire-prone old-growth ponderosa pine forests have relatively open understories and patches of regeneration, whereas old-growth mixed-conifer forests in the same landscape have dense understories. These structural compositional differences affect stability, resistance, and ecological characteristics. For example, in the absence of fire, open, old-growth ponderosa pine forest can develop into dense mixed-conifer forests that have a lower resistance to high-severity fire than does fire-dependent pine old growth.

Old growth is a complex ecological concept that requires a multiscale perspective ranging from individual live or dead trees, stands or patches, and landscapes, to whole regions. At broad scales, the old growth is clearly part of a mosaic of open, young and mature forest types. A comprehensive strategy, which is currently lacking in the Plan, to conserve any one stage of this mosaic requires considering all stages (Spies 2004). Although the structures associated with these old-growth (for example, large live and dead trees, patchiness) typically develop and appear in old stands, they can also be found in young forests as survivors of disturbance. Thus, the ecological contributions of old growth can occur in stands of all ages.

Given the complexity of forest development and the concept of old growth, definitions used for inventory (Moeur and others 2005) can only be approximations. Inventorying the amount and distribution of old-growth forest by all of the attributes that have been associated with it and using the same inventory tools is impossible. For example, remote sensing can be used to estimate the size of trees in the upper canopy and characterize spatial patterns, but it cannot be used to estimate dead wood and understory patchiness. Inventory plots can be used to characterize the size distribution of live and dead trees, but they cannot be used to measure spatial pattern. Inventory information is a composite of surrogates from remote sensing (for example, size of canopy trees) or nonspatial structural information from inventory plots (dead wood and tree size distributions). For this reason the monitoring plan recommended a two-pronged approach—remote sensing and inventory plots—for assessing the amount and distribution of forest conditions (Hemstrom and others 1998).

The new perspectives on old-growth complexity underscore the need to adjust conservation and management strategies to forest types and environments. For example, old-growth goals and strategies could differ by province, potential vegetation type (plant association groups), and disturbance regime. The Plan recognized this complexity to some degree, but more could be done to incorporate it into practice. For example, specific older forest definitions are lacking for dry old-forest types and for younger forest stages or mixes of younger and older forests. Clarification of the definitions of older forest stages and their significance for the Plan is important for the following reasons:

The Plan is based on conservation of a particular stage or stages of older forest. Without a clear definition or set of definitions, the goals of the Plan become confusing and difficult to communicate.

Because forests are dynamic systems, conservation of a single stage, even a long-lived one, is really impossible without considering other stages and transitions among them. For example, many of today's mature forests will be the old-growth forests of the future, and today's old-growth forest may be the early-successional forest of the future. If the Plan focuses exclusively on one or more older stages, it may not sustain native biological diversity associated with other stages.

Current Amounts of Old Growth Compared to the Historical Conditions

Conservation concerns about biodiversity in this region stem from the observation that amounts of old growth and associated forest structures (large live and dead trees) have declined strongly over the 20th century as a result of logging and wildfire (Bolsinger and Waddell 1993). Fire suppression has also contributed to the loss of some fire-dependent old-growth types. References to past forest conditions can be problematic, however, because forest landscapes are dynamic and the amount of any particular forest compositional or structural type will differ depending on the time and location of the observation. Recognizing these inherent dynamics, ecologists have developed the concept of historical range of variation (HRV), which is the range of variation in forest attributes that might be expected in a landscape over time under a particular disturbance regime (for example, frequency, type, and severity) (Landres and others 1999).

Historical range of variation in forest age or stage classes can be a useful context for understanding the state of present landscapes (Agee 2003, Wimberly 2002). For example, the percentage of old forest (forests >200 years old) in the Oregon Coast Range was estimated to range between about 25 and 75 percent of the forest area (Wimberly and others 2000). For forests more than 80 years old, Wimberly and others (2000) estimated the range to be about 50 to 85 percent. Today, the amount of old-growth forest containing 39.4-inches diameter trees, size diversity, and large amounts of standing and fallen dead wood is estimated to be around 1 percent of that province (Ohmann and others, in press). (The smaller proportion of old growth in Coastal Oregon estimated by Ohmann and others [in press] compared to Moeur and others [2005], probably results from the fact that Ohmann used a more restrictive structural definition.) In the central eastern Cascades of Washington, Agee (2003) estimated that multistoried old-growth forest covered 38 to 63 percent of the landscape. Comparable estimates of current amounts were not made in that study. Moeur and others (2005), however, estimated that the percentage of older forest in the eastern Cascades of Washington—an area that encompasses the Agee (2003) study—was about 12 percent, with older forest defined as medium and large trees whose diameter limits differ by species and site productivity.

The HRV was used in the ecosystem assessment in FEMAT to describe possible Plan outcomes. But the original evaluations of various options showed that reaching that range may not be possible in future landscapes given possible changes in climate and disturbance regimes. The concept of variation in amounts of old and young forest over time does have value in understanding the degree of change that has occurred and in setting general expectations for landscapes, where native biodiversity is a dominant management goal. Even with disturbance regimes and climate change, a range of forest ages and structures will typically be present in landscapes over time if disturbances are spread across all stages, which would usually be the case under natural disturbance regimes including fire, wind, insects, and disease.

The HRV studies have shown that landscapes the size of large national forests (that is, >1,235,527 acres) were unlikely to be completely covered by old forests (Wimberly and others 2000). For example, in the Oregon Coast Range, a mosaic of open, young closed-canopy and older stages is more likely (Nonaka and Spies 2005). Current policies on federal lands in wetter provinces could lead to more old growth than would be expected under the historical wildfire regime.

History of Development of Old-Growth Stands

Several studies in the Pacific Northwest have examined how old-growth stands have developed over time (Poage and Tappeiner 2002, Weisberg 2004, Winter and others 2002). In the moist provinces, these studies confirm the model set forth by Franklin and Hemstrom (1981) of stands with a wide range of ages of the dominant Douglas-firs, implying slow establishment after fire, a history of moderate-severity fire that results in regeneration of Douglas-fir, or both. Studies of stand development history are less common in the dry provinces. Where studies have been done, the range of age variation in the older trees is wide; old trees established almost continuously over several centuries as a result of frequent low-severity fires (Sensenig 2002).

Studies also indicate that many old-growth stands in the moist provinces developed from young stands with low stem densities compared with today's forest plantations (fig. 6-7). The densities of young stands will influence the diameters of the trees when they reach old age (Poage and Tappeiner 2002). Not all stands developed with multiaged old trees; some older forests have relatively uniform-aged canopy trees (Winter and others 2002), although this pathway seems to be less common across the Plan area than the multiaged pathway.

Much has been learned in the last 10 years about the diversity and role of fire in the development of old growth. Increasingly, the variation in disturbance regimes across the Plan area is appreciated (Brown and others 2004, Sensenig 2002, Weisberg and Swanson 2003). Although the role of fire in creating structural complexity in old growth was known for the dry types with frequent fire-return intervals, the role of fire in the west side was less appreciated. Typically, fire on the west side was largely seen as a destroyer of old growth. Recent research (Weisberg 2004) confirms the understanding that fire in mixed-fire-regime landscapes on the west side contributes to a particular spatial pattern and structure of old-growth Douglas-fir and western hemlock forests.

Tom Spies

Figure 6-7—Dense young plantation and old-growth stand in the western Oregon Cascades.

Silviculture to Restore Ecological Diversity and Accelerate Old-Growth Development in Plantations

The effects of thinning on the long-term development of old-growth characteristics in plantations are understood only from modeling studies and just a few years of experimental work. Retrospective studies of old-growth development have also provided insights useful to understanding how silviculture might affect old-growth development (Tappeiner and others 1997).

Results thus far show that thinning plantations is important to restoring structural and compositional diversity on federal lands. Dense young plantations (fig. 6-7) have lower species diversity than more heterogeneous young stands, and they may not develop old-growth characteristics like large trees and complex canopies as rapidly as less dense young stands. Thus, the goals of thinning are really twofold: diversify young stands now and accelerate the developing of old-growth characteristics in the future.

The literature supports the practice of thinning to increase species diversity in stands (Muir and others 2002). Many ecologists believe that thinning for biodiversity goals should seek to promote spatial heterogeneity in stands, rather than the uniform spacing and density of trees produced in thinning for timber production. Spatial variation in stand density creates a diversity of microsites and promotes species diversity. Leaving some areas of stands unthinned is important to provide the shaded microclimates favored by some species. For example, some species of bryophytes have been shown to decline in thinned areas compared with unthinned areas (Thomas and others 2001). The most effective spatial patterns of thinning in young stands to create ecological diversity are not known and probably vary across the Plan area. Caution needs to be exercised in applying the same spatial pattern of thinning in all areas and at all spatial scales, since scientific research on this practice is only in the early stages.

The effects of thinning on development of old-growth characteristics in plantations are only partially understood. Certainly, the growth of trees into larger diameter classes will increase as stand density declines (Tappeiner and others 1997). At some point, however, the effect of thinning on tree diameter growth levels off and, if thinning is too heavy, the density of large trees later in succession may eventually be lower than what is observed in current old-growth stands. In some cases, opening the stand up too much can also create a dense layer of regeneration that could become a relatively homogenous and dominating stratum in the stand. Furthermore, if residual densities are too low, the production of dead trees may be reduced (Garman and others 2003). Thinning should allow for future mortality in the canopy trees. Modeling studies indicate that thinnings in plantations could accelerate development of some old-growth characteristics by as much as 60 to 80 years, depending on the thinning regime and the age of the plantation at initial entry. Multiple thinning entries typically had more effect than a single entry.

Data from implementation monitoring (Baker and others, in press) are not adequate to evaluate the degree to which thinning operations were conducted in plantations in late-successional reserves. The implementation report indicates that a total of 287,414 acres was treated with partial removal, which includes commercial thinning but not precommerial thinning. If we assume that 30 percent of the late-successional reserves (based on the fact that most reserves contain a significant area of plantations) are in plantations suitable for thinning, then 2.2 million acres would potentially be eligible for thinning at the beginning of the Plan. If the treated acres reported by Baker and others (in press) were all thinnings in late-successional reserves, the amount of plantations thinned thus far would be about 13 percent of the total in 9 years, or a mean annual rate of 1.4 percent. At this rate of thinning, 71 years would be needed to thin all of the plantations at least once, and many would become too old for thinning (80 years) under the ROD before they were treated. Better data are clearly needed to evaluate the scope of the problem, but these limited data show that the rate of thinning may not be coming close to meeting the need and intent of the Plan. The implication is that many stands are exposed to blowdown and other disturbances, and could experience delayed structural development, jeopardizing their expected contributions to the biodiversity goals of the Plan. For example, if left untreated, the plantations would probably develop fewer very large trees (for example, >60 inches d.b.h.) in 100 to 200 years than occur in many of today's old-growth stands.

Why Do Some Species Occur More Commonly in Older Forests?

The distinctive plant, animal, and fungal communities of old-growth forests are typically associated with the habitat elements such as large trees, dead and down trees, and microclimates. Species associated with habitat structure include the northern spotted owl and the marbled murrelet. Another reason for the occurrence of species in old growth is simply the passage of time (Halpern and Spies 1995). Unique species may occur in old growth because enough time has elapsed since major disturbance that species with relatively weak dispersal powers can colonize and grow. Old-growth-associated species that disperse in this way include some vascular plants (Halpern and Spies 1995) and some lichens and bryophytes (Muir and others 2002). The implication for the Plan is that the occurrence of some rare species may not be accelerated through manipulations of forest structure. These species may simply require long periods to recolonize forests after stand-replacement disturbance. Such species would potentially be retained through natural and managed disturbances that leave structures (for example, large live and dead trees) and patches of forest (for example, patch retention, riparian zones) that become refugia from which the species could recolonize younger forests. The presence of some old-growth-associated species in predominantly young forest is associated with survival of large old trees (Sillett and Goslin 1999).

The Effect of Natural Disturbances on the Abundance and Spatial Pattern of the Late-Successional Reserve Network

At current rates of disturbance, the regional late-successional reserve network still appears robust, and losses would be replaced by growth of smaller diameter stands into larger diameter classes. In some dry provinces, however, the rates of disturbance have been higher, and the risk of substaintial loss of old forest is high. Although this risk was recognized by FEMAT and the ROD, implementing fuel reduction activities has apparently not been sufficient to reduce risk of stand-replacement disturbances. The risk assessment of FEMAT for these dry provinces is consistent with the fire condition class analysis (Schmidt and others 2002), which rated most of these areas as condition class 3, forests that have been significantly altered by fire exclusion and whose ecosystem components are at high risk of loss to fire. Under changing climate, increased threats to old forests from high-severity disturbances in dry provinces and other disturbances could lead to declines in the abundance of older forests resulting in increased gaps in the reserve network among and within provinces.

Fire-Prone Forests

The Plan distinguished two major fire-regime zones: the low-frequency, high-severity regimes of the northern and west-side provinces and fire-prone forests of the eastern and southern provinces (for example, eastern Cascades, Klamath, and southern Cascades) characterized by historical regimes with high frequency (fires every 10 to 50 years) and low to mixed severity (fig. 6-8). A third type was not included: the moderate- or mixed-severity fire regime (Agee 1993, Brown and others 2004). This type is typically found in the western Cascade provinces where the fire regimes are a complex mixture of stand-replacing and low-severity fires. It is also found in the fire-prone provinces where topography creates a complex mosaic of fire regimes (Agee 2003). The assumption that the approaches to conserving older forest (that is, standards and guidelines) should be different

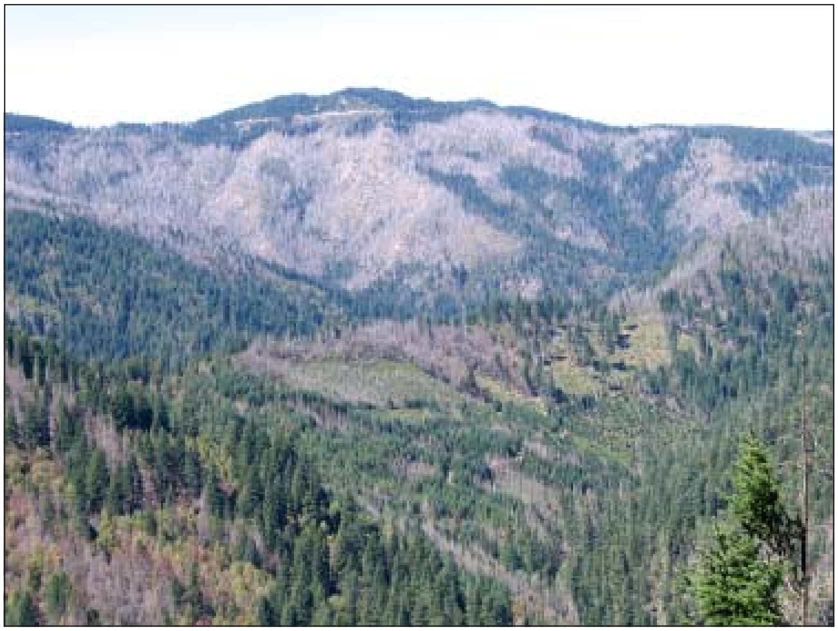
Tom Spies

Figure 6-8—Patchy pattern of fire mortality resulting from the 2002 Biscuit Fire in southwest Oregon.

for the fire-prone and fire-infrequent regions of the Plan still holds. Although fuel reduction treatments such as cutting out small-diameter understory trees and prescribed fire are less necessary in the mixed-fire-regime areas because these forests were naturally more dense under the historical regime (Brown and others 2004), fire suppression in these types could alter their structure and function in the future (Weisberg 2004). Recent fire-history research supports a strategy in which management activities, such as thinning and prescribed burning, take into account variation within those major zones that result from climate, topography, and vegetation types (Camp and others 1997, Wright and Agee 2004).

The Plan recognized the increased risks to old growth in fire-prone forest types and identified that fuel reduction activities would need to be carried out in late-successional reserves to restore desired old-growth structures and reduce risk of stand-replacement fires in old growth and owl habitat. The assumption that fuel reduction will reduce probability of high-severity fire is still valid (Graham and others 2004), although many of the large fires in the region are limited more by climate than by fuel.

The standards and guidelines clearly allowed for manipulations to reduce risk of loss to stand-replacement fires in the dry provinces. Such manipulations were probably not at a high enough rate to significantly reduce the probability of stand-replacement fire in dense old growth in these provinces and restore the open old-growth types. In 2003, the only year for which data exist, it was estimated that fuel reduction activities were applied on 131,603 acres (Baker and others, in press). These data are very weak, however, in that they do not cover all forests in the Plan area and some of the data come from forests not entirely in the Plan area. A crude estimate of the upper limit of the annual area needed for treatment by mechanical means or prescribed fire can be made by estimating the area of fire-prone forest types (all ages and allocations) in the dry provinces (about 12 million acres), and assuming that 80 percent of these landscapes (9.6 million acres) were characterized by low-severity, high-frequency fires with a return interval of less than 25 years (Agee 1993, Taylor and Skinner 1998). If the low end of this frequency (25 years) was restored through active management on these 9.6 million acres, then 384,000 acres would need to be treated every year. That amount would be at least three times the area treated in 2003. The acres treated might actually have to be much higher initially because some stands might need to be treated mechanically before using prescribed fire. In practice, the area treated would be governed by landscape patterns of topography, accumulated fuel, and other objectives. Consequently, not all acres and allocations potentially eligible for treatment would need to be treated. Nevertheless, the total area treated is still probably much less than is needed. The relatively low rate of fuel treatments may have several causes including lack of funding, legal challenges, and risk aversion on the part of stakeholders, regulators, and managers. For example, the Fish and Wildlife Service concluded in one opinion that thinning around an owl nest would constitute "take" of an endangered species (Irwin and Thomas 2002). Everett and others (2000) estimated that a large proportion of area would need to be burned every year in the eastern Washington Cascades to maintain landscape heterogeneity and reduce hazard from high-severity fire.

The standards and guidelines for these provinces appear to limit thinning in old forests in reserves. For example, although FEMAT and the standards and guidelines in the Plan recognized the need for mechanical treatments and prescribed fire to reduce risk of stand replacement in these forests, they do not clearly state that large areas would need to be treated and that the dual goals of owl habitat and old-growth ecosystem diversity and function cannot be met without a landscape (midscale) strategy. These goals are often in conflict in the fire-prone provinces (Irwin and Thomas 2002) where owl habitat has increased in some forest types (for example, ponderosa pine) as stands have become dense, shade-tolerant tree species (for example, *Abies* spp.) have filled the understories, and fires have been excluded. The standards and guidelines first emphasized treating young stands in the late-successional reserves, but they are more cautious when it comes to treating older forests in reserves. For example, they stated that activities should "be focused on young stands," but that actions in older stands may be appropriate as long as "they do not prevent the late-successional reserves from playing an effective role in the objectives for which they were established" and "should not generally result in degradation of currently suitable owl habitat." This language is somewhat ambiguous and conflicting, especially at the stand scale, where simultaneously reducing risk of loss to large pines and Douglas-firs by thinning out mid- and lower-story trees is impossible without reducing the quality of owl habitat.

Landscape-level (midscale) strategies would identify key places for treatments, including repeated treatments. Without this approach, the likelihood of sustaining suitable owl habitat will remain low. It is important also to recognize that these treatments will not prevent losses of owl habitat to wildfire. Consequently, plans assume losses will occur and allow for replacement habitat over the landscape as a whole.

Salvage in Late-Successional Reserves After Stand-Replacement Disturbance

The Plan assumed that some old forests in late-successional reserves would burn in high-severity fire during the lifetime of the Plan and that the area and number of reserves was sufficient to maintain old-growth functions in spite of this loss. The goal of the reserves has clearly emphasized conservation and restoration of late-successional forest including old-growth forest. When those forests are burned by high-severity fire, 100 to 200 years or more may elapse before they return to older forest conditions. The ecological influences of old growth do not end with the death of the tree layer in a high-severity fire, however. Biological legacies of old growth, including dead trees, surviving live trees, and other organisms and organic matter carry over into the young forests and can persist for many decades as the new younger forest develops (Harmon and others 1986). For example, significant amounts of dead wood from the previous stand can be found 100 years later in postfire stands, and trace amounts can be detected in some 200-year-old stands (Spies and others 1988). The amount and duration of this legacy wood varies greatly with species, climate, and disturbance history. The "connected old-growth network" is more than a spatial concept—it is also a temporal one, in which developmental stages are connected to each other through surviving and slow-decaying structural and compositional components of previous stages.

The Plan was somewhat vague, however, when it came to the role and management of these postfire stages in reserves. The standards and guidelines about salvage in late-successional reserves acknowledge that guidelines are intended to prevent "negative effects on late-successional habitat while permitting some commercial wood volume removal." They go on to state that some salvage may actually facilitate habitat recovery (for example, making it easier to regenerate the site) or reduce the risk of future stand-replacing disturbances.

The ROD could be interpreted in at least two ways:

- Salvage is permitted only for ecological goals that maintain or enhance late-successional habitat with commercial wood volume as a byproduct; or
- A removal of "conservative" quantities of salvage material is permitted for commercial objectives.

Several arguments can be made in support of the first interpretation. First, although a high-severity fire would kill an old-growth forest, it does not remove all of the late-successional habitat elements that will be in the young forest for many decades. Thus, removing any large dead trees would diminish amounts of late-successional habitat elements in young forests. Second, these early-successional stages, with many large dead trees, contribute to an important but not often stated goal[2] of the Plan, which is to maintain biological diversity. The stage of natural stand development after stand-replacement disturbance in old forest is particularly rare. It was not common in landscapes under a historical disturbance regime (Nonaka and Spies 2005), but occasionally it was widespread after large fires. This stage has become very rare in an era of fire suppression, salvage logging, and plantation forestry. Third, salvage of dead old-growth trees would not be consistent with the precautionary principle (Kriebel and others 2001) that underlies much of the Plan's design and implementation.

At the time of the Plan, the ecological values of dead wood were known (Harmon and others 1986, Thomas 1979). Although little new research has been conducted on the ecological effects of salvage logging after stand-replacement disturbance since the Plan was adopted, the ecological value of large dead trees in early-successional forests has been reaffirmed in several synthesis papers on the subject (Beschta and others 2004, Lindenmayer and others 2004, McIver and Starr 2000). In addition, no empirical evidence has emerged that salvage logging can improve the desired ecological diversity of young forest or the development of late-successional forests later in succession. Brown and others (2003) found some indication that removing large dead trees could reduce the spread and severity of reburns that often follow high-severity fires. The magnitude of this effect is unknown, and the indirect effects of salvage logging—including soil disturbance and increased fine fuel from slash left on the site—may outweigh any benefits of removing large fuel.

Several arguments can also be made for the second interpretation of the standards and guidelines for salvaging in reserves. First, option 9 in FEMAT allowed salvage for disturbances larger than 24.7 acres. Second, the language in the standards and guidelines implies that, where salvaging is done it should "retain snags that persist until late-successional conditions have developed" (C-14). In fact, very few of the fire-killed trees will persist until the next late-successional forest develops in 100 to 200 years. Most trees will decay and disappear well before the next older forest (Spies and others 1988); however, some small fraction of biomass could persist. Thus, most of the smaller diameter trees would not persist for long periods and would not meet persistence criterion. Third, the allowance of some commercial wood production in this case would meet one of the President's principles, which was to provide for economic

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[2] See appendix B-1 in the ROD (USDA and USDI 1994).

and social values after meeting the criteria of the environmental laws. Removing trees for commercial purposes could also be justified in supporting the management infrastructure needed to carry out the broader goals of ecological restoration, which are typically underfunded.

The primary benefit of the large snags is in the first few decades, first as standing dead trees and in subsequent decades as fallen trees. Smaller diameter trees (for example, <20 inches d.b.h.) and species with high decay rates (for example, hemlock and true firs) could be salvaged with much less effect on biological diversity. The particular effects of different rates of salvaging operations on ecological functions in reserves are generally unknown. Consequently, scientifically identifying amount of salvaging that "should not diminish habitat suitability now or in the future" is probably impossible (C-13) for the foreseeable future.

In conclusion, the ROD did leave open the possibility of salvage logging for commercial purposes in the reserves after large stand-replacing disturbances, but it also clearly states the ecological value of dead and live trees in these situations. The ROD did not indicate any specific amounts of salvage logging that would be compatible with the major goals of the Plan. Essentially, no new scientific studies have emerged on either side of the debate that can shed light on the essential question: How much salvaging could be done before habitat suitability is diminished now or in the future? New studies outside of the Pacific Northwest indicate that widespread salvage logging can negatively affect many taxa and ecosystem processes (Lindenmayer and others 2004), but widespread salvaging was not the intent of the salvage guidelines in the ROD. An interpretation of the ROD that no salvage logging for commercial purposes should occur in late-successional reserves would largely be based on the general ecological values associated with dead trees in postfire vegetation, and application of the precautionary principle. An interpretation that allowed limited salvaging in reserves would be based on the judgment that the economic benefits of commercial production would be greater than the negative effects on ecological values associated with reserves.

Reforestation in Late-Successional Reserves Following Wildfire

Natural regeneration typically occurs after fire in most of the forests of the region. Consequently, reforestation activities in late-successional reserves following fire are often not needed. However, the densities of regeneration can vary widely across the region, and in some situations reforestation may be warranted. For example, where seed sources of dominant conifers, such as ponderosa pine and Douglas-fir, have been lost through historical cutting of individual large trees and recent high-severity fire, some planting may be needed. Studies in southwestern Oregon showed that natural conifer regeneration can be difficult to obtain on many sites because of moisture limitations and competition with sprouting shrubs and trees (Minore and Laacke 1992). If timber production is a goal, planting and treatments of competing vegetation are clearly needed to establish conifer plantations. The amount of planting needed to restore structurally diverse forests in dry landscapes is not known, however. Historical studies of old forests have shown that natural regeneration and development of young stands took many decades, and the densities of trees in these young stands were often relatively low. In some dry landscapes, open brush fields probably persisted for long periods as trees slowly invaded. These shrubby areas were important to the general biological diversity of the landscape and can contribute nutrients such as nitrogen by nitrogen-fixing shrubs. If recent fires have had a much higher proportion of high-severity damage than in the past, then it is possible that vegetation development after these fires would be quite different than under natural disturbances, where patches of surviving old trees and seed sources would have been common in postfire landscapes. Under these circumstances, some reforestation could be justified for ecological goals.

The Plan Is Based on the Geographic Distribution of a Single Species

The Plan assumed that a region defined by the range of a single species, the northern spotted owl, could form the basis of a cohesive unit for ecosystem management. The region encompassed a wide range of ecosystem types and disturbance regimes. The Plan attempted to deal with variability in that area through province and watershed analyses, geographic variation in standards and guidelines, and adaptive management areas distributed across the Plan area. In the first decade of implementation, however, the diversity of approaches appears to be much less than was intended. Consequently, the use of a single species to define the boundaries of a complex ecosystem plan is difficult to defend ecologically or administratively.

Treatment of the Matrix for Both Ecological Values and Commodity Production

The ecological value of leaving large live trees as individuals and groups as a way of supporting older forest species in areas managed for timber production has been supported by habitat studies of individual species (Sillett and McCune 1998). In addition, fire history studies show that many old-growth stands may have gone through periods in which the stand was partly or almost completely killed by disturbance. Approximating some of the characteristics of these natural disturbances with green-tree retention harvesting approaches in the matrix is consistent with this information. Despite the technical and scientific basis of commodity production from the matrix, harvest of older forest did not occur. No new scientific evidence has emerged that the standards and guidelines for the matrix, which allowed cutting of old trees, would not meet the ecological and viability goals of the Plan.

The Reserve Strategy of the Plan

The Plan has sometimes been criticized for using a reserve-based approach. At other times, it has been criticized for not placing all of the remaining old growth into "true protection," such as a park or wilderness area. These criticisms imply that "reserve" means one thing—a no-touch-no-management zone and that a reserve approach is either not valid for dynamic forests or is the only way to conserve the old growth. The reality is that conservation biology and the Plan rest on various kinds of reserves and protected areas. Most of the protected areas allow active management for ecological goals, and the matrix allows active management for a blend of commodity and ecological goals. As implemented, however, the differences among the land allocations have been much less than intended.

A reserve is defined as an "area of land especially dedicated to the protection and maintenance of biological diversity, and natural and associated cultural resources, and managed through legal or other effective means" (IUCN 1994). It has also been defined as, "extensive tracts managed primarily to perpetuate natural ecosystems and related processes, including biota" (Lindenmayer and Franklin 2002: 75). According to these authors, reserves are to provide:

- Examples of [natural] ecosystems, landscapes, stands, biota, etc. and contribute to natural evolutionary processes.
- Strongholds for sensitive species (for example, particular habitats or species sensitive to human intrusions).
- Control areas against which to measure effects of human activities.

Reserves are an administrative or legal vehicle to reach an ecological goal rather than the goal itself. In other words, species and ecosystems do not respond to why people's activities vary across a landscape—only that they **do** vary. The ecological goals for reserves are typically so generally defined "for example, natural processes and ecosystems" that specific measures of success do not exist other than the goal of keeping direct human effects out of the area. If "natural"—little or no human presence—is the goal, then all ecological states, species, and ecosystems that develop are equally desirable. Ecological conditions in a reserve may conflict with more specific vegetation or habitat goals for species or landscapes, however. Northern spotted owl habitat in fire-prone landscapes is a good example of this conflict.

The Plan contains many types of reserves or protected areas. All of these reserve strategies are consistent with internationally recognized approaches to conservation (table 6-3). A similar although simpler set of protection classes has been developed by the Gap Analysis Program of the U.S. Geological Survey (http://www.gap.uidaho.edu/).

Note that several of these protected areas allow active management to achieve ecological goals. For example, the late-successional reserves are closest to International Union for Conservation of Nature (IUCN 1994) category IV, which allows active management for habitat and conservation objectives. Note also that the last category of protection, code VI, actually allows for producing wood products. In fact, the entire federal forest landscape has many of the attributes of IUCN-protected category VI because under the Plan, biodiversity goals are paramount, sustainable use of forests is also a goal, and no large commercial plantations are allowed (matrix standards and guidelines with green-tree retention do not create standard commercial plantations).

The notion of reserves implies the existence of a surrounding landscape that is not reserved or is a "matrix" of other uses, typically commodity production. Normally, the matrix is the dominant land area and the reserves are embedded in it. In the Plan, however, the matrix in most provinces is not the majority of the federal landscape. The Plan has created a situation in which the "matrix" in the sense of the dominant landscape is really the reserves, and the commodity production areas are minority land allocations that are embedded in those areas. In another sense, the true matrix for the federal land is the nonfederal land, where commodity production is typically the major goal. The implication of this structure is that, because this reserve network covers very large areas, many of them in fire-prone forest types, losses of old forest will undoubtedly happen regularly within the network. Because the reserve system is so extensive, it was hypothesized that it would be robust to these losses. In most forest regions of the world, reserves are a relatively small part of the forest. Consequently, losses to habitat within these small areas can be devastating; it is less of a problem here, although, in some provinces the sizes of the disturbances can be large. The assumption that the reserve network was sufficient to meet the Plan's goals has never been examined at province or larger scales as part of its adoption. At the landscape level, only the Blue River Landscape Study (Cissel and others 1999) addressed this issue.

The federal matrix was intended to allow stand-replacement logging for commodity production, but the logging has not been done to the degree expected. Consequently, the matrix and the reserves have been treated similarly in terms of regeneration harvesting and the rate of planned, stand-replacement disturbances. Consequently, the production of diverse early-successional forests, which would have been a byproduct of green-tree retention logging practices in the matrix, has not happened. In dry provinces this early-successional habitat has developed from wildfires; in wetter provinces, however, this habitat has probably declined, generally reducing seral-stage diversity on federal lands.

Forests are dynamic but reserve boundaries are not. This reality raises the question of whether a reserve-based strategy is the best approach. The Plan's reserves are not no-touch zones, especially in the fire-prone provinces, and the large size of the reserve network means that it is relatively robust against high-severity disturbances. Still, examining alternatives would be helpful, to see if more effective strategies exist to meet the Plan's ecological goals.

One approach might be to move reserve boundaries after a stand-replacement wildfire. Some adjustments to reserves can be consistent with the Plan (FEMAT 1993: VIII-30; USDA and USDI 1994: E-18) and adaptive management. However, moving late-successional reserve boundaries as a standard response to high-severity fire in late-successional and old-growth forests was not part of the Plan

Table 6-3—Correspondence of Plan land allocations to International Union for Conservation of Nature (IUCN) protected-area categories

	IUCN characteristics			
Plan allocation	**Closest IUCN category**	**Code**	**Goal**	**Human intervention**
Research natural area	Strict nature reserve	Ia	Science	Minimal
Wilderness (29 percent of Plan area)	Wilderness area	Ib	Natural character and absence of human impacts	Minimal
National park including wilderness	National park	II	Ecosystem protection and recreation	Localized impacts, restoration
Administratively withdrawn (7 percent of area)	Natural monument	III	Specific natural feature	Possibly restoration
Late-successional reserves (44 percent of area)	Habitat, species management area	IV	Conservation through management intervention	Restoration, active management for ecological goals only
No counterpart in Plan other than some Native American sites	Protected landscape	V	Desired cultural (historical) landscapes containing human interactions with nature	Traditional or historical (pre-industrial) uses
Entire federal landscape including reserves (~50%) and matrix (~20%)	Managed resource protected area	VI	Sustainable use of natural ecosystems with biodiversity protection paramount	Limited harvesting allowed to provide a sustainable flow of natural products, no large commercial plantations

and may require a reexamination of network and other components (for example, key watersheds, aquatic habitat). The interconnectedness of the Plan's conservation strategies[3] makes it difficult to modify any single part of it without potentially compromising its goals.

Alternatives to the Plan's reserve strategy exist, and their suitability depends on the particular desired balance between ecological and commodity goals, the decision process used to manage the forests, and the natural dynamics of the forest landscapes. The following are several possibilities:

- Structure-based management. This approach would have no fixed reserves and the entire landscape would be managed for both ecological and commodity goals to be achieved through variable timber rotations ranging from standard industrial rotations to rotations of 150 years or more (ODF 2001). Green-tree retention may be practiced with regeneration harvests. This approach was briefly considered during FEMAT, but it was rejected for several reasons: to meet commodity objectives would require the logging of large areas of existing old growth; it was unknown how well sensitive species, processes, and habitats could be maintained entirely through managed systems; risks to viability of late-successional species were considered too large, it would not produce the full diversity of old-growth forest conditions (for example, forests older than 400 years) and functions that currently exist in the region; and the road systems required to maintain active management across the landscape could be detrimental to the other goals.
- Temporary reserves. Under this approach, a reserve would exist until the trees are killed in a stand-replacement disturbance. At this point, the reserve would revert to the matrix allocation or an adaptive management area. Unless new reserves were designated, the approach would be problematic for Plan goals because, over time, the forest would change from reserves to more active management, changing the mix of biodiversity and commodity goals.
- Hybrid of disturbance-based management and reserves. The Blue River Landscape Study is an example of this approach (Cissel and others 1999), which demonstrates how watershed analysis in the Plan could have been used to revise the spatial pattern of allocations and management prescriptions based on knowledge of fire history and landscape dynamics. Reserves are designated, but the boundaries and their landscape distribution are fundamentally different from the Plan's. Riparian reserves are blocked into larger patches, leaving matrix areas larger and more operationally feasible. The matrix is managed on longer rotations (with greater live and dead tree retention) producing less of a gap in midaged stands (80 to 200 years) in the long run than under the Plan in which the matrix would largely be less than 80 years and the reserves would largely be over 200 years old. This plan assumes continued cutting of some older forest but at a lower rate than would happen in the Plan. Although this approach has less area in reserves than does the Plan, it produces less timber than would be expected under the fully implemented Plan because of long rotations and higher retention of live trees.
- Reserve all remaining old growth or mature and old growth. Under this approach all old-growth forests—including those in the matrix—would be reserved from logging. The timber production goals would have to come from younger natural

[3] Option 9 was an attempt to achieve efficiency through coordination of aquatic and terrestrial strategies and ecosystem and species strategies.

forests and existing plantations. The effects of this alternative would depend on the definition of old forest, the expected rate of timber production, and the kind of activities permitted in the reserves. This approach would have some elements of option 1 from FEMAT, in which most of the remaining old forest was reserved and the largest numbers of species were considered to have sufficient habitat. The long-term effects of this approach are uncertain. If plantations were the main location of regeneration harvest, such an approach might perpetuate undesirable spatial patterns that were set earlier under different forest management objectives. If pattern goals were part of this strategy, some plantations would have to be excluded from the timber production base, which would reduce expected timber outputs. This approach would require a different strategy in the fire-prone provinces where open, fire-dependent old-growth types have largely been replaced by late-successional types with dense understories of shade-tolerant conifers. In many areas, selective logging of large pines and Douglas-firs has removed the large tree components. Thus, reserving the old-growth in these landscapes means locating the large remaining trees and using them as foci for restoration activities that would include thinning, mechanical fuel reduction, and prescribed fire. Timber production in these types would have to come from smaller diameter trees that were removed in the process of protecting old, large trees. Of course, to meet owl habitat objectives, areas of dense late-successional old-growth forest would have to be retained.

- Landscape restoration in fire-prone provinces. The most urgent need for improving the effectiveness of the Plan lies in the fire-prone provinces. The standards and guidelines for reserves and matrix do not adequately address the landscape perspectives that are really needed to conduct ecosystem management in these areas. This approach is not simply a matter of abolishing all land allocations and using a "shifting mosaic" approach to management. The owl's habitat requirements necessitate zoning the landscape both to provide the appropriate amount and spacing of owl habitat and to prioritize fuel treatments based on plant association groups and the landscape ecology of fire. We do not know how close the current pattern of Plan allocations comes to landscape zoning where the goal is to reduce risk to loss of owl habitat from fire and pathogens. It seems likely that a more effective landscape strategy could be developed, especially given the losses of owl habitat that have already occurred in many provinces and the fact that matrix lands currently appear to be managed as though they were late-successional reserves (that is, little cutting of older forest for timber goals). Of course, any landscape plan would be subject to the unpredictable elements of natural disturbances, which can only be treated in a probabilistic sense. High-severity fires would still occur under more effective fuel reduction strategies, but management actions could reduce their effects.

Developing a new strategy for implementing the Plan in the fire-prone provinces is beyond the scope of this document, but whatever strategy is developed could include:

- More explicit guidelines on balancing the area of dense older forests for northern spotted owl habitat and for other species, and the risks of loss of those habitats from the stand-replacement disturbances that are more likely in dense forests. For example, how large should the habitat areas be, and how should they be placed to reduce risk of loss of habitat areas? How should the habitats be placed relative to the potential vegetation (plant association groups) and disturbance regimes?

- A strategy to retain large-diameter trees for ecological and social reasons; for example, what diameters and species should be retained in restoration activities in matrix and late-successional reserves?
- A more explicit approach for restoring open old-growth forest types and landscape patterns and reducing the probability of high-severity fire. This approach would be more explicit and emphatic about the need for active management, including mechanical treatments, prescribed fire, and reestablishing seed sources of desired tree species over large areas and across all allocations. For example, what stand-level prescriptions should be used, and how should they be distributed across landscapes?
- A more explicit plan for providing a sustainable flow of commodities and revenues that could be used to finance restoration programs and support local communities in these provinces.

The Role of Nonfederal Land

The Plan addressed management only on federal land. Although relation to nonfederal land was considered, FEMAT did not analyze conditions or plans for nonfederal land other than for timber production. The Plan essentially did not assume any contribution of nonfederal land to late-successional goals. The FEMAT did call for working with nonfederal landowners to coordinate management across watersheds and provinces as part of an "integrated approach to ecosystem management for nonfederal lands" (FEMAT 1993: VIII-39). No evidence suggests that this occurred to any large degree, however.

The Plan made several fundamental assumptions about nonfederal forest land.

1. The nonfederal land would contribute little to the late-successional goals.

The inventory data suggest that this is not entirely true. The status and trend report shows that significant areas of stands with medium-sized trees (>20 inches d.b.h.) exist off of federal lands (table 6-1). This is particularly true in the coastal provinces of Oregon and California, where federal lands occupy a minority of the area and where highly productive private forests occur that can grow stands with average stem diameters of 20 inches in 60 to 70 years (McArdle and others 1961). Large-diameter (>29.5 inches) multistoried forest occurs predominantly on federal land, although at least 20 percent occurs off of federal land, probably largely on other public ownerships. On these other ownerships, this older forest is more likely to be in smaller patches or have had a history of logging that reduced other structural elements, such as dead wood. Within the nonfederal land, medium and large multistoried forest covers about 17 percent and 3 percent, respectively, of the forest-capable acres (Moeur 2004).

Some research has also shown that this assumption (No. 1) is not necessarily true (Holthausen and others 1995, Spies and Johnson 2003). In fact, some nonfederal forest management practices have incorporated elements of late-successional conservation objectives. For example, state forests in coastal Oregon have adopted plans that would increase the amount of mature forest in that landscape (ODF 2001) over what it would have been if those lands were managed under an industrial forestry model. Simulation projections showed that indicators of old-growth forest structure and spotted owl habitat will increase strongly on those state forests in the northern Coast Range, although they will not reach the amounts on federal lands in that province (Spies and others, in press). Private forest lands will not contribute much to older forest habitat values, but the area of stands with large-diameter trees may show small increases as a result of stream-side protection rules in Oregon and Washington, and some habitat conservation plans for northern spotted owls are on those lands.

2. The federal land alone could meet the biodiversity needs of focal species and ecosystems without contributions from the nonfederal lands.

This assumption also is not necessarily true. Research in coastal Oregon shows that the highest potential coho habitat is not on federal land, where stream gradients are relatively steep, but on private lands and especially on nonindustrial private lands, where stream gradients are gentler and more conducive to coho habitat (Burnett 2004). Furthermore, in coastal Oregon, about one-third of moderate- to high-quality marbled murrelet habitat is on nonfederal land in the Coast Range of Oregon, and almost 60 percent of moderate- to high-quality red tree vole habitat is on nonfederal land. Some ecosystem types that are regionally threatened, such as oak woodlands, are primarily on nonfederal land as are many large river flood plains and wetlands.

3. Federal land alone could meet Plan goals in spite of contradictory influences from nonfederal lands.

The assumption that activities on adjacent nonfederal lands would not negatively influence desired conditions on federal lands is questionable, but it remains untested in provinces, landscapes, and watersheds dominated by nonfederal lands. This assumption is especially questionable on BLM land. For example, in the Oregon Coast Range, 70 percent of BLM land falls within 3,280 feet of nonfederal land (Spies and others 2002). Here, forests on federal lands may be at greater risk of invasion from nonnative species, diseases, and fires that may originate on other ownerships with higher densities of roads, seed sources for nonnative species, sources of fire ignition from human activities, and fuel configurations that facilitate the spread of fire. The magnitude of these influences has received relatively little study, but it could be high in some areas.

The Plan also made implicit assumptions that emphasis on protecting and restoring late-successional habitats and species would not jeopardize the viability or diversity of other species or ecosystems not directly associated with older forest or, in other words, that a plan that focused on older forest would also provide for other elements of biological diversity. Although it was not stated explicitly, it may have been assumed that nonfederal land would provide for other non-late-successional species that were not provided for on federal land.

This assumption is not necessarily valid. Again, research in the Oregon Coast Range indicates several trends. First, successional diversity will decline on federal land as succession moves stands and landscapes toward dominance of late-successional habitats. This trend will be mitigated by any regeneration harvesting in matrix areas and by natural stand-replacement disturbances from fire, wind, and pathogens. In some provinces, however, stand-replacement disturbances will be infrequent, and many landscapes will become dominated by older forests. Second, some vegetation types will decline on all ownerships because no forest plans will provide for them. For example, hardwood forests in coastal Oregon are projected to decline because federal plans exclusively emphasize late-successional forests and private forest lands emphasize the growth of conifer plantations. Although hardwoods could develop as a result of unplanned disturbances, such as landslides, debris flows, and wildfire, most management plans have worked to greatly reduce the incidence of these disturbances. Third, diverse early-successional forests with old-growth legacies are also expected to decline. Disturbances that create these legacies are suppressed on all ownerships, and postdisturbance practices on nonfederal ownerships typically work to reduce early-successional structural and compositional diversity. Although a goal for the federal land is to achieve high amounts of older forest, forest history studies and simulation modeling suggest that, under natural disturbance regimes, landscapes were not totally dominated by old forest, and forest landscapes were characterized by an intermixing of early-, mid- and late-successional forest types (Nonaka and Spies 2005).

The Plan also explicitly assumed that a comprehensive, integrated assessment of forest ecosystem management could be conducted by focusing primarily on late-successional forests with the federal land. Given the interconnectedness of forest ecosystems and landscapes, this focus means that the ecosystem assessment for the Plan was incomplete. For example, it did not assess the consequences of the development of a bifurcated forest condition across the region in which federal land is dominated by older forest managed primarily for biodiversity goals and nonfederal land is dominated by younger forest managed for timber and other goals. This emerging pattern has implications for regional biodiversity, spread of fire and other disturbances, and protecting biodiversity on nonfederal lands. For example, when considered at a regional scale, the biodiversity protections on federal land may allow for timber production on nonfederal land with minimal habitat protection for some endangered species. On the other hand, landscape- and province-scale analysis shows that because of the mix of forest goals, some habitat types (for example, hardwoods, diverse early-successional vegetation) may strongly decline, with uncertain effects.

Climate Change Effects

Climate change was identified as one of the sources of uncertainties in meeting the outcomes described in the species and old-growth ecosystem assessments. The assessments for option 9 in FEMAT stated the likelihood of not achieving the most desired outcomes at about 20 to 30 percent. Climate change effects on Plan outcomes have not been formally analyzed. The consensus of the scientific community that climate change will occur has probably broadened since the Plan was developed (Oreskes 2004). The significance of these changes to the Plan is still uncertain.

The most recent climate-change scenarios for the Pacific Northwest include (JISAO 1999):

- Increased moisture stress followed by a decline in the area of forest land as a result of drought, and increased disturbances from insects and fire. These would largely be at the current margins of forest and nonforest plant communities (for example, East Cascades).
- An initial decrease in summer moisture stress as a result of higher precipitation, leading to an initial expansion of forests at the margins, followed by increased moisture stress and forest dieback as temperatures rise further.

Keeton and others (in press) pointed out that the second scenario probably is less likely than the first because summer precipitation would have to increase substantially (20 to 30 percent) for it to improve the typical summer moisture deficits. In either case, climate change effects within the Plan area are most likely to be at lower elevations, in drier provinces at ecotones between forest and nonforest areas. Many of these effects would be manifest as increases in disturbance frequency and severity of fires, wind, disease, and insect outbreaks.

Considerations for the Plan

The Plan, whose outcomes were expected to evolve over a century, is already making a difference. After 10 years of monitoring, the status and trends in abundance, diversity and ecological functions of older forest are generally consistent with expectations. Although the total area of older forest has increased, and overall losses from wildfires are in line with what was anticipated, losses to fire are high within the fire-prone provinces. Given the relatively short time for monitoring and the lack of reliable information about future losses from high-severity wildfires and climate change, significant uncertainties remain about the long-term trends in old forests.

Information from implementation monitoring suggests that rates of fuel treatments and restoration of structure and disturbance regimes in fire-dependent older forest types have been considerably less than is needed to reduce potential for losses of these forests to high-severity disturbance and successional change. Restoration activities in plantations are apparently also less than what is needed in moist provinces.

Landscape management strategies that balance reducing fuels with maintaining owl habitat have not been developed, but they could reduce the potential for future high-severity fires that destroy both owl habitat and the large conifer trees that serve as the building blocks of old-growth forest restoration.

Reexamination of the Plan’s reserve strategy and alternatives indicates that active management in reserves, both dry and wet forests, would restore ecological diversity and reduce the potential for loss from high-severity fire.

Monitoring trends and reevaluation of Plan assumptions do not indicate a compelling reason for major changes to reserve boundaries in moist habitats at this time. In dry provinces, however, new landscape management strategies could be evaluated to determine if they would reduce risks of loss of older forest and owl habitat compared to what is currently in the Plan.

Given that the Plan has not been implemented entirely as intended (for example, the matrix is essentially being managed similarly to the late-successional reserves) alternative landscape-level strategies to the Plan could be considered in an adaptive management context to determine if other approaches might better meet the goals of the Plan.

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Chapter 7: Conservation of Listed Species: the Northern Spotted Owl and Marbled Murrelet

Martin G. Raphael

Introduction

The statement of mission for the Forest Ecosystem Management Assessment Team (FEMAT) directed the team to take an ecosystem approach to forest management and particularly to address maintaining and restoring biodiversity. In addressing biological diversity, the team was directed to develop alternatives that met the following objective FEMAT (1993: iv):

> …maintenance and/or restoration of habitat conditions for the Northern Spotted Owl and the Marbled Murrelet that will provide for viability of each species—for the owl, well distributed along its current range on federal lands, and for the murrelet so far as nesting habitat is concerned.

In this chapter, I describe the expectations of the Northwest Forest Plan (the Plan) in meeting this biodiversity objective and assess how successful it has been in its first 10 years. In judging progress, keep in mind that the Plan's outcomes were expected to evolve over a century and longer. Thus, discerning progress after only the first decade is difficult. But a focus on the Plan's progress in meeting these goals for two wide-ranging vertebrates, the northern spotted owl and marbled murrelet (see appendix for scientific names), both of which are listed as threatened under the Endangered Species Act (ESA 1973), is certainly warranted.

Northern Spotted Owl

The northern spotted owl conservation strategy embodied in the Plan evolved from designation and protection of a large number of relatively small management areas for individual pairs of owls to an approach based primarily on the designation of fewer large areas, each designed to support multiple pairs of owls. The scientific basis for the current strategy was developed by the Interagency Scientific Committee (ISC), (Thomas and others 1990). The ISC articulated five general principles from the field of conservation biology that formed the scientific underpinning of their owl conservation strategy:

- Species that are well distributed across their range are less prone to extinction than species confined to small portions of their range.
- Large blocks of habitat, containing multiple pairs of the species in question, are superior to small blocks of habitat with only one to a few pairs.
- Blocks of habitat that are close together are better than blocks far apart.
- Habitat that occurs in less fragmented (that is, contiguous) blocks is better than habitat that is more fragmented.
- Habitats between blocks function better to allow owls to move (disperse) through them the more nearly they resemble suitable habitat for the species in question (that is, blocks that are well connected in terms of habitat are better suited than blocks that are not).

Using these principles, the ISC called for the delineation and conservation of blocks of suitable northern spotted owl nesting, roosting, and foraging habitat (hereafter termed "habitat"), most large enough to support 20 or more pairs of owls and spaced no more than 12 miles apart, and the provision of dispersal habitat in areas between blocks of nesting habitat.

The FEMAT incorporated the northern spotted owl conservation principles from the ISC as well as broader considerations for other species associated with late-successional and old-growth forest, functional old-growth ecosystems, and aquatic ecosystems, and developed 10

Mature spotted owl.

management options. One of these, option 9, was selected and further developed, eventually becoming the Northwest Forest Plan. All of the options included extensive reserve systems, that is, federal land reserved from planned commercial timber harvest and for which the primary objective was maintaining and restoring late-successional and old-growth forest. These reserves included wilderness and national parks, other administratively withdrawn lands, and two new classes of reserves called late-successional reserves (LSRs) and riparian reserves. In the Plan, these LSRs were designed to include the best of remaining late-successional and old-growth forest, termed older forest, along with key watersheds (FEMAT 1993), and additions to meet the recommendations from the ISC and the draft northern spotted owl recovery plan (USDI 1992). Riparian reserves were buffers along permanent and intermittent streams where forest habitat is to be retained (See Reeves, chapter 9 this volume). Under the Plan, these riparian reserves were assumed to provide connectivity among the larger LSRs to support owl dispersal.

What Was Expected Under the Plan?

The FEMAT (1993) used an expert panel to assess the sufficiency of habitat on federal land to support a viable population of the northern spotted owl for 100 years. The panel considered four possible outcomes, labeled A through D. Under outcome A, habitat was judged to be of sufficient quality, distribution, and abundance to allow the owl population to stabilize, well-distributed across federal lands over the next 100 years. Note that this outcome does not imply a **constant** population, but rather one that might vary around some nondeclining mean population. Under outcome B, habitat would allow the owl population to stabilize but with significant gaps in the historical distribution that could cause some limitation in interactions among local populations. Under outcome C, habitat would be so limited as to allow owl persistence only in refugia with strong limitations on interactions among local populations. Outcome D represented extirpation of owls from federal lands. The expert panel assigned an 83-percent likelihood to outcome A and an 18-percent likelihood for outcome B with no likelihood of outcomes C or D for option 9, the option that eventually was developed as the Plan. Thus, the panel's assessment was the high likelihood that habitat conditions on federal land would allow the northern spotted owl population to stabilize and be well-distributed throughout its range. Note also that additional features added to option 9 after FEMAT in the record of decision (ROD), (USDA and USDI 1994b), such as an increase in the width of riparian buffers on intermittent streams and protection of 100-acre areas around owl activity centers in the matrix, would likely provide for an even higher likelihood in outcome A had these features been evaluated by the expert panel. In summary, the Plan "would adequately provide for the continued viability of the northern spotted owl on federal lands as required by the National Forest Management Act (NFMA 1976) and furthermore would provide the federal lands' contribution to recovery of the northern spotted owl under the Endangered Species Act (ESA 1973)" (USDA and USDI 1994b: 31). I emphasize, however, that this projection was based on whether habitat conditions on federal lands would support owls. The panels recognized that the cumulative effects of habitat conditions on nonfederal lands, interactions with the barred owl, and other factors outside the scope of the Plan, would produce much greater uncertainty in the projected likelihood of owl persistence. The FEMAT also assessed option 7, an option that was based on provisions of the draft recovery plan for the owl and which was very similar to the proposals of the ISC. Outcomes for that option were lower than option 9, with likelihood scores of 71, 25, 4, and 0 for outcomes A, B, C, and D.

Clearly, over the long term, the Plan was expected to provide for a well-distributed and viable population of the owl, but no quantitative description of expected short-term trends was forthcoming. Several qualitative descriptions exist, however. Because the Plan is based so strongly in the ISC recommendations, it is instructive to examine its expectations. The ISC wrote (Thomas and others 1990: 35):

> An implied assumption of this conservation strategy is that the owl population will reach a new, stationary equilibrium at some future time. We are confident in this assumption, even though the amount of suitable habitat and the number of owls will continue to decline over the short term. We hypothesize that once the rate of loss of suitable habitat outside HCAs [habitat conservation areas] comes into balance with the rate new habitat is recruited within the HCAs, a stable equilibrium will be attained. This equilibrium will, of course, be at a lower population number than existed historically. Further, because the northern spotted owl has a low reproductive potential, considerable time may be required for the population to stabilize at a new equilibrium number.

The ISC anticipated declines of up to 50 to 60 percent of the current owl population under their conservation strategy. The northern spotted owl recovery team projected that owl habitat and owl numbers would continue to decline for up to 50 years before reaching a new equilibrium under the draft recovery plan, which was very similar to the ISC strategy in the size and number of its habitat reserves (USDI 1992).

The Plan provides for a 52-percent larger system of habitat reserves than did the ISC strategy (comparing options 7 and 9, in the final supplemental environmental impact statement [FSEIS], tables 3 and 4 in USDA and USDI 1994a: 38). Under the Plan, owl numbers and amounts of habitat were still expected to decline but at a slower rate than under the ISC strategy. Habitat was expected to decline from timber harvest by about 2.5 percent per decade (USDA and USDI 1994b: 46). In the FSEIS, continuing population declines were also expected. It discussed at some length whether, given the results of demographic studies showing declining survival rates of adult owls, the owl population might have passed a population threshold from which it could not recover. The 1993 demographic analysis (Burnham and others 1996) estimated a 4.5 percent annual decline (confidence interval = 0.7 to 8.4 percent annual decline) in the population of territorial adult owls. In considering available evidence, the FSEIS team concluded that the basis for believing that owl populations have passed or would soon pass a threshold was not strong. This conclusion was supported by Raphael and others (1994), who performed a series of owl population simulations based on projected habitat trends under assumptions of option 9. These spatially-explicit population models suggested that populations might decline in most provinces for the first 40 to 50 years, but populations in all areas would eventually stabilize and begin increasing as habitat recovery exceeds losses. In the Oregon provinces, populations did not show initial declines. Raphael and others (1994) accounted for timber harvest outside of the reserves, and for ingrowth of habitat in the reserves, but did not model losses of habitat to fire or other catastrophic events. In these simulations, Raphael and others did not account for habitat that might be on nonfederal land.

The northern spotted owl monitoring plan also provided several qualitative descriptions of anticipated trends in populations and habitat (Lint and others 1999):

- Owl populations are expected to continue to decline over the short term with the decline proceeding at a faster rate for owls in the matrix than in reserves.
- In the longer term, owl populations in reserves are expected to be self-sustaining as individual reserves reach a condition where at least 60 percent of the land area is owl habitat.

- Habitat conditions within reserves will improve over time at a rate controlled by successional processes in forest stands that currently lack the vegetation structure to be owl habitat.
- Habitat conditions outside of the reserves will generally decline because of timber harvest and other habitat-altering activities, but the vegetation structure across the landscape will continue to facilitate owl movements.
- Catastrophic events are expected to halt or reverse the trend of habitat improvement in some reserves; however, the repetitive design of the reserves should provide adequate resiliency in the reserve network, so catastrophic events do not result in isolating segments of the owl population.

What Has Happened to the Owls and What Differences Were Found Between Expectations and Observations?

Baseline habitat—

The Plan was designed by using many of the principles of conservation biology and was expected to conserve much of the remaining northern spotted owl habitat in large reserves. Davis and Lint (2005) used a modeling approach to define and map owl habitat. They first defined "habitat-capable" lands as those areas capable of growing forest within the elevation range in which owls are known to nest. Then, using a software package called BioMapper[1], Davis and Lint classified habitat-capable lands into habitat suitability for nesting, roosting, and foraging ranging from 0 (lowest suitability) to 100 (highest suitability). The resulting habitat suitability maps depict the full range of scores, from 0 to 100. In some cases, reporting amounts of northern spotted owl habitat required setting a threshold for suitability and tallying all acres that exceed that threshold. Davis and Lint generally chose to consider areas with scores greater than 41, based on the range associated with 90 percent of known owl sites, to define a range that is most similar to areas where owls were known to occur. Under that criterion, about 42 percent of land capable of supporting owl habitat (42.9 million acres of all federal and nonfederal lands) is on federally administered land within the Plan area. Federal land supports 58 percent of high-suitability owl habitat (suitability score >41) and 42 percent is on nonfederal land (Davis and Lint 2005) over the entire owl range (table 7-1, fig. 7-1). It is likely that habitat on nonfederal land is in smaller, more fragmented patches than habitat on federal land. On federal land, about 60 percent of habitat-capable land is in reserved land-use allocations (excluding riparian reserves, which are not mapped) and 65 percent of known owl habitat is in those allocations (table 7-1, fig. 7-1). Davis and Lint assumed that as much as 50 percent of the habitat-capable lands in adaptive management areas and the combined matrix/riparian reserves would be reserved, and under that assumption they estimated that over 80 percent of the habitat-capable acres with habitat suitability >40 would occur in a reserved land-use allocation. In Washington, Oregon, and California, percentages of owl habitat in reserves (not counting riparian reserves) are 79, 61, and 61, respectively. This indicates that the reserved land allocations were somewhat successful in including the most suitable habitat.

The FSEIS estimated that about 66 percent of the extant owl habitat (totaling about 7.4 million acres on federal land) would be in congressionally reserved areas and late-successional reserves (USDA and USDI 1994a: 222). Davis and Lint (2005) estimated that about 59 percent of owl habitat (that is, habitat with suitability score of 41 or greater, totaling 10.3 million acres on federal land rangewide) would be in these two types of reserves. Additional habitat is reserved under other land-use allocations such as administratively withdrawn areas, riparian reserves, marbled murrelet reserve areas (LSR3), and 100-acre northern spotted owl core areas (LSR4). The areas of these types of reserves are difficult to compare between Lint's analysis and the FSEIS because the FSEIS did not report these areas, so

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

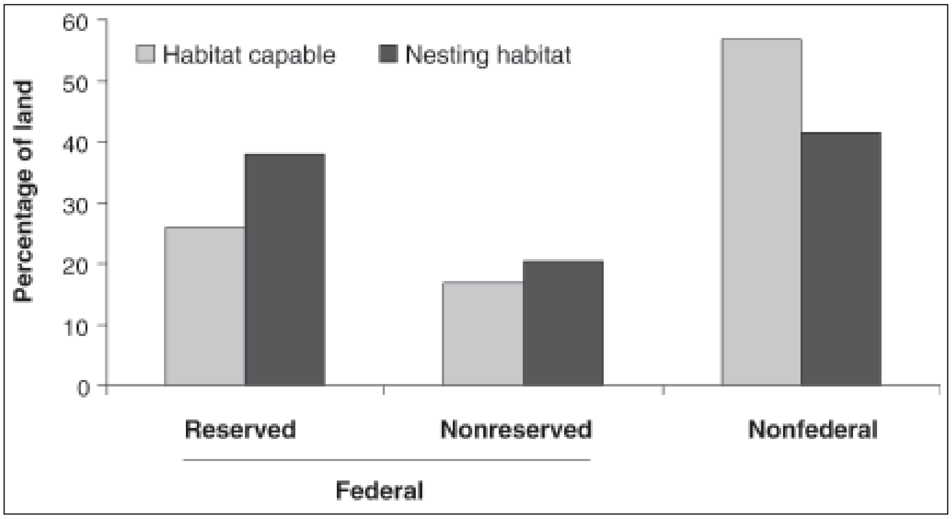

Figure 7-1—Distribution of northern spotted owl habitat on federal and nonfederal lands compared to amounts of habitat-capable forest land in the Plan area (after Davis and Lint 2005).

here we focus on the congressionally reserved and late-successional reserve areas. Davis and Lint's (2005) analysis suggests a smaller proportion of owl habitat was retained in these two land-use designations than was estimated in the FSEIS. Also apparent is that Davis and Lint's estimate of the total amount of baseline habitat is greater than was estimated in the FSEIS. The difference in amount is a consequence of the difference in methods used to classify habitat and because the FSEIS did not include estimates for USDI Bureau of Land Management (BLM) and National Park Service (NPS) lands in California (FEMAT 1993: IV-38); I believe the Davis and Lint estimates are an improvement over previous estimates because the data and methods used to classify habitat were more consistent across the owl's range.

Habitat losses—

The expected rate of loss of owl habitat from timber harvest on federal land was 2.5 percent per decade (USDA and USDI 1994b: 46). Davis and Lint (2005), using change detection methods from Moeur and others (2005), estimated that losses on federal land from stand-replacing harvest of owl habitat (that is, losses of acres with habitat suitability scores of 41 or greater) were 0.25 percent, rangewide, over the past 10 years and differed by state: losses totaled 0.11 percent in Washington, 0.35 percent in Oregon, and 0.19 percent in California (table 7-1). Among provinces, losses were greatest (0.79 percent) in the California Cascades; no other province lost more than 0.5 percent. Clearly, loss of habitat from timber harvest on federal land (at least those losses from stand-replacing harvest) was below the expected 2.5 percent per decade. There were no estimates of expected rates of loss on nonfederal land. Observed harvest rates were substantially greater on nonfederal land than on federal land: losses on nonfederal land totaled 7.8 percent rangewide, 12.0 percent in Washington, 10.8 percent in Oregon, and 2.3 percent in California.

Losses of habitat from wildfire were greater than losses to timber harvest. Although losses from catastrophic events such as fire or windthrow were anticipated, I found only one quantitative estimate of expected rates for such events: FEMAT (1993: IV-55), in conducting simulation studies to estimate forest development, assumed that 2.5 percent of reserved areas (on average over the Plan area) would be subject to severe disturbance per decade. Observed rates averaged over the entire Plan area have been lower than the FEMAT estimate, but rates on the Oregon Klamath, Eastern Cascades of Washington, and California Cascades provinces were greater than 2.5 percent per decade (Spies, Chapter 6,

Table 7-1—Estimated amount of northern spotted owl habitat at the start of the Northwest Forest Plan (baseline, 1994) and losses owing to regeneration harvest and stand-replacing fire from 1994 to 2004, by state and by ownership

	Higher suitability nesting habitat (HS > 40)[a]				
	Baseline	Losses[b]			Change
Land class	(1994)	Fire	Harvest	Total	1994-2004
	– – – – – – – – *Thousand acres*			– – – – – – – –	*Percent*
Federal reserved					
WA	1,964.5	4.2	0.4	4.6	0.2
OR	3,002.5	81.7	1.6	83.3	2.8
CA	1,754.4	30.3	.9	31.2	1.8
Range	6,721.4	116.2	2.8	119.0	1.8
Federal nonreserved					
WA	531.4	2.4	3.2	5.6	1.1
OR	1,944.4	10.6	15.7	26.3	1.4
CA	1,104.8	3.7	4.1	7.8	.7
Range	3,580.6	16.8	23.1	39.9	1.1
Nonfederal					
WA	1,748.3	.6	209.6	210.2	12.0
OR	2,906.0	4.0	310.6	314.6	10.8
CA	2,910.7	3.7	63.3	67.0	2.3
Range	7,565.0	8.3	583.5	591.8	7.8
All lands					
WA	4,244.2	7.2	213.2	220.4	5.2
OR	7,852.9	96.3	327.9	424.2	5.4
CA	5,769.9	37.7	68.3	106.0	1.8
Range	17,867.0	141.3	609.4	750.7	4.2

[a] See Davis and Lint (2005) for methods of defining habitat suitability (HS).

[b] Data summarized from Davis and Lint (2005) and Davis (personal communication). Losses represent stand-replacing events, not partial harvest.

this volume). Davis and Lint (2005) estimated rangewide losses of 1.3 percent of habitat-capable acres with a habitat suitability >40 from wildfire on federal lands (table 7-1). Most of this loss was in the Klamath Province of Oregon after the Biscuit Fire. In that province, 6.6 percent of owl habitat was lost, mostly in large reserves. Rates of loss in all other provinces were less than 1.5 percent. Rates of loss to fire totaled 0.4 percent in Washington, 1.9 percent in Oregon, and 1.3 percent in California (table 7-1). Losses to fire were less on nonfederal land, totaling 0.1 percent rangewide. Losses on nonfederal land were 0.03 percent in Washington, 0.1 percent in Oregon, and 0.1 percent in California (table 7-1).

On average, the combined loss from harvest and fire on all land totaled 4.2 percent rangewide during the Plan's first 10 years (table 7-1). The rate of loss was greatest in Oregon (5.4 percent). Loss totaled 5.2 percent in Washington, and 1.8 percent in California (table 7-1). The total loss from harvest and fire on federal lands (1.5 percent) was substantially lower than was assumed in the FEMAT simulations (5.0 percent).

Bigley and Franklin (2004) summarized changes in owl habitat as part of the recently completed northern spotted owl status review (Courtney and others 2004). They relied on estimates of loss compiled from agency records by the USDI Fish and Wildlife Service (FWS). The FWS numbers

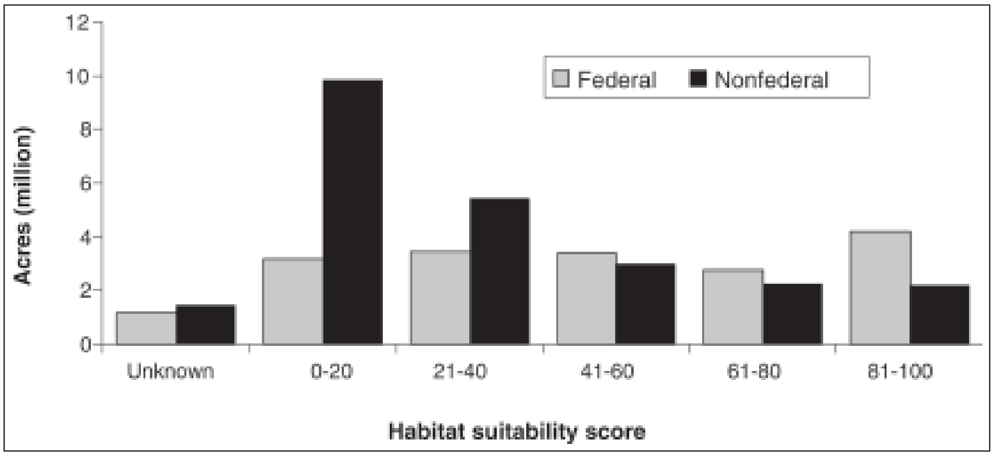

Figure 7-2—Estimated amounts of northern spotted owl nesting habitat on federal and nonfederal land within the Plan area, by groupings of habitat suitability scores (after Davis and Lint 2005).

differ from those summarized in Lint (2005), primarily because the FWS definitions of suitable owl habitat differed, the FWS used agency records rather than satellite-based change detection, and because the FWS included partial harvest in their calculations (Moeur and others 2005 were not able to estimate acres of partial harvest by change detection methods). I do not know the extent to which partial harvest affects owl habitat: some amount of harvest may improve habitat in parts of the owl's range and may degrade habitat in other parts of the range. The FWS reported a loss of 380,000 acres of owl habitat from 1994 to 2003; 156,000 from harvest and 224,000 from natural events (fire, wind, insects, and disease). The FWS baseline was 7.4 million acres, similar to that used in the FSEIS. The rate of loss was thus 5.1 percent per decade, an estimate more than twice that of Davis and Lint's estimate, but roughly in line with assumptions in FEMAT and the ROD (2.5 percent loss from fire and 2.5 percent loss to harvest, totaling 5.0 percent per decade).

Habitat increases—

Amounts of habitat were expected to increase over time as young forests mature and gain the characteristics of suitable owl habitat. Davis and Lint (2005) were not able to fully account for growth of owl habitat. The increases in older forests found by Moeur and others (2005) have yet to be assessed for characteristics of suitable owl habitat, but Davis and Lint (2005) suggested that longer term increases in amount of habitat will accrue for forest that is currently in the lower suitability classes (that is, those acres currently scoring in the 21 to 40 range). They further suggested that the greatest increases in habitat will likely be in the Western Cascades of Oregon and Washington, the Klamath Provinces of Oregon and California, and the Coast Range Province of Oregon where more than two-thirds of the habitat-capable Plan acres are located.

As shown in figure 7-2, the amount of habitat-capable land area with suitability scores ≤40 is larger on nonfederal lands. This might reflect the heavier rates of timber harvest on those lands. In addition, based on current harvest practices on most nonfederal lands (for example, short rotations), amounts of forest with these lower suitability scores will likely not progress toward higher scores over time as they are anticipated to do on federal land (as older plantations develop into habitat). In other words, low-suitability nonfederal habitat is probably more static, and recruitment of future habitat will mostly occur on federal land. On federal land, habitat recruitment can be anticipated from forest with habitat suitability ≤40.

In summary:

- Most owl habitat is on federally administered lands, but a substantial amount of habitat (42 percent) is on nonfederal lands.

- Nonfederal habitat may not function as well as federal habitat in supporting owls to the extent it is in smaller more fragmented patches.
- Most (65 percent) of habitat on federal land is in reserved land allocations.
- Losses of habitat on federal land from harvest were variable across the owl's range; losses from harvest were less than expected under the Plan.
- Additional losses of owl habitat resulted from fire and other disturbances, which were most severe in the Oregon Klamath province because of the recent Biscuit Fire, and rangewide loss of habitat from fire was lower than expected under the Plan.
- Loss of owl habitat to harvest was much greater on nonfederal lands.
- Some evidence showed a net increase in amounts of mature forest (stands greater than 20 inches d.b.h.) during the first 10 years of the Plan, but how much of this increase is owl habitat is unclear.

Population trends—
Estimates of northern spotted owl population trends derived from the most recent demographic analyses are fully described in Anthony and others (in press) and in the northern spotted owl status and trend report (Lint 2005). These reports provide a full explanation of the methods and details of the analyses; here I extract a few of the key results:

- The rangewide population, averaged across all 13 demographic study areas, declined by 3.7 percent per year from 1990 to 2003 (weighted mean lambda = 0.963, SE = 0.009). "Lambda" is a measure of the rate of population change; a value of 1.0 indicates a stationary population, a value less than 1.0 indicates a declining population, and value greater than 1.0 indicates a growing population. A declining population is consistent with the expected trend; the rate of decline is greater than one might have predicted from the rate of habitat loss and is less than the 4.5 percent annual decline that had been estimated from the 1993 demographic analysis. The estimated rate of change was based on a different analytical model in the 1993 analysis (see Boyce and others 2005 for a discussion of the newer approach) and so estimates from the 1993 and 2004 analyses are not directly comparable.
- Rates of decline vary across the owl's range, with the greatest decline (and an accelerating rate of decline from higher rates of mortality) in Washington and the northernmost Oregon site (weighted mean lambda = 0.925, SE = 0.008) and lower rates of decline in the remaining study areas in Oregon and California (weighted mean lambda = 0.980, SE = 0.004).[2] Populations were declining in Washington and the northernmost study area in Oregon, where apparent survival rates were declining on those five study areas. Populations were essentially stationary on the remaining five study areas in Oregon (that is, the 95 percent confidence intervals around lambda overlapped 1.0). Variation in rates of population change in different parts of the owl's range was expected, based on known differences in amounts and distributions of habitat across the range and based on evidence from the simulation modeling. The magnitude of decline and accelerating rate of decline in Washington was not expected, however, nor was the apparently stationary trend in parts of Oregon.
- Realized population change in Washington indicated a loss of 40 to 60 percent of the initial population in those study areas during the 13 years of study (illustrated for one study area in figure 7-3; note the wide confidence interval around this

[2] G. Olson, 2005. Personal communication. Assistant professor, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

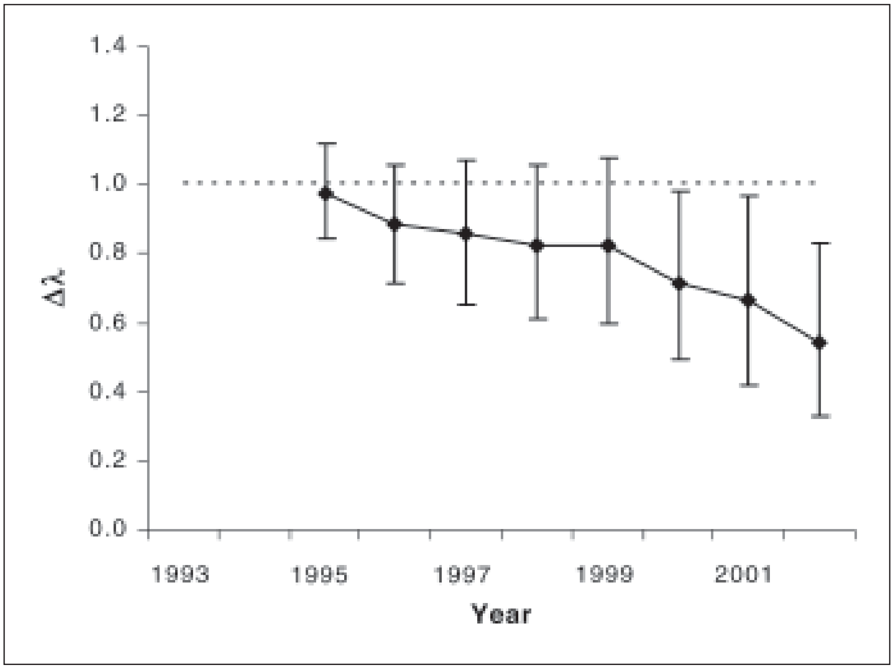

Figure 7-3—Cumulative population change (realized lambda) of northern spotted owl populations on the CleElum study area, Washington, 1995 to 2002. The horizontal dotted line denotes a stationary population (lambda = 1.0). Values (with 95 percent confidence intervals) denote the proportion of the starting population that is still present at each successive year (from Anthony and others, in press).

cumulative effect). This rate of loss had been expected over 40 to 50 years under the ISC strategy, which would have conserved much less habitat than is conserved under the Plan.

Extent to Which Differences Were Caused by the Plan

Trends in the amount and distribution of northern spotted owl habitat on federal land were strongly influenced by the Plan. The system of reserves and the restriction on harvest of owl habitat through various standards and guidelines outside of reserves has done much to conserve and restore owl habitat. Clearly, the rate of loss of northern spotted owl habitat from timber harvest on federal lands has been reduced since the implementation of the Plan (see chapter 3, fig. 3-1d). About 42 percent of current owl habitat is on nonfederal land, over which the Plan has little influence. Some influences from large reserves on federal land have affected management of habitat on nonfederal land, in that state and private entities have tied conservation of owl habitat on their lands to adjacent federal reserves (Pipkin 1998). Current habitat has been and will continue to be harvested faster from nonfederal land than from federal land.

Habitat has been lost to fires, insects, and disease, and much of the lost area is in large reserves, especially in the drier provinces with nonlethal frequent fire regimes. Active management of forests in fire-prone areas of the eastern and southern parts of the owl range to reduce risk of catastrophic losses has not been as extensive as envisioned under the Plan. To date, the loss of owl habitat to fire, although locally important (as in the Biscuit Fire), has not been extensive rangewide (see chapter 6). Failure to implement some of the provisions for risk management, however, has increased the risk of future losses of habitat in dry provinces, and may reduce the potential for owl persistence in affected reserves in those areas. Overall, though, the replication of reserves provides a buffer against losses to fire and other catastrophic events.

Northern spotted owl populations have continued to decline, despite the lower than expected rate of habitat loss. The rangewide rate of population decline is similar to the rate that had been observed at the start of the Plan and continues to be cause for concern. If this rate were to continue, the owl population could decline by 66 percent in three decades. Populations in Washington are declining faster than elsewhere, and the rate of decline has accelerated over the past 10 years. Several factors could contribute to this decline, including the lingering effects of past timber harvest, continuing logging on nonfederal land, forest succession and suppression of fire, defoliation from insects, and interactions with the barred owl. Blakesley and others (2004), in their summary of northern spotted owl demographics as part of the status review, suggested that circumstantial evidence points toward interactions with the barred owl as the most likely cause of the decline in the northern part of the owl range. They also pointed out that owl populations in the northern range may be more susceptible to prey shortages, higher energy expenditure, and more extreme weather. In support of this possibility of interactions between habitat quality and weather, Franklin and others (2000), in their California study, found that owls in territories with high-quality habitat had greater survival during inclement weather than those in poor-quality habitat. Available data are not sufficient to establish direct cause-and-effect relations, but the loss of habitat in Washington during the past 10 years is not a likely cause of the higher rate of population decline there, because the rates of habitat loss in Washington are lower than rates elsewhere where owl populations have been stationary. The bottom line is that the Plan has been successful in conserving remaining owl habitat on federal lands, and the reserve system has provided for restoration and increases in habitat over time, but the relationship of habitat to population trend has not been straightforward.

Although conservation and restoration of habitat are essential to northern spotted owl conservation, habitat protection alone may not be sufficient to conserve and restore owl populations. Other emerging threats, such as the barred owl, may cause continuing declines even though habitat conditions are otherwise sufficient to support stationary or increasing owl populations. For example, recent studies in Oregon and Washington (Kelly and others 2003) found that northern spotted owls were displaced from territories when barred owls were observed within 0.5 mile of the territory center. Species irruptions of this type are beyond the control of habitat managers, and the Plan itself cannot prevent irruptions of invasive species. The redundancy built into the reserve design may yet allow for some level of coexistence of northern spotted owls and barred owls, but no agreement has been reached among experts on whether the two species will indeed coexist or whether the barred owl will eventually overcome and displace the northern spotted owl from major portions of its range. In the recent scientific evaluation of the status of the spotted owl, Gutiérrez and others (2004) described several alternative hypotheses about the results of interactions between spotted owls and barred owls:

Clearly plausible:

- Barred owls will replace the northern spotted owl throughout its range (behavioral and competitive dominance hypothesis).
- Barred owls will replace the northern spotted owl in the northern, more mesic areas of its range (moisture-dependent hypothesis).
- Barred owls and northern spotted owls will compete, with the outcome being an equilibrium favoring barred owls over spotted owls in most but not all of the present spotted owl habitat range (quasi-balanced competition hypothesis).

Plausible:

- The barred owl will replace the northern spotted owl over much of its range, but the spotted owl will persist in some areas with management intervention (management hypothesis).

- Barred owls will replace the northern spotted owls in the northern part of its range but the spotted owl will maintain a competitive advantage in habitats where its prey is abundant and diverse (specialist vs. generalist hypothesis).

Not plausible or not clear:

- Barred owls will replace the northern spotted owl over much of its range, but the spotted owl will persist in refugia (refugia hypothesis).
- Barred owls will replace the northern spotted owl in some habitats but not in others (habitat hypothesis based on structural elements of forest, which confer a maneuverability advantage to the smaller spotted owl).
- Barred owls will increase to a peak number, then decline or stabilize at a lower density, which will permit the continuation of spotted owls (dynamics hypothesis).
- Barred owls will replace the northern spotted owl only where weather and habitat perturbations have placed spotted owls at a competitive disadvantage (synergistic effects hypothesis).

Other emerging threats to the northern spotted owl are outside of direct control under the Plan. The West Nile Virus (genus *Flavivirus*) (the virus) arrived in the United States in 1999 and has expanded into the West. This virus is known to cause widespread mortality in wild birds, and one captive northern spotted owl is known to have died from it. Blakesley and others (2004) said that the virus could reduce population viability throughout the owl's range, but they also say that the degree to which this potential will be realized is uncertain. They point out that, on one hand, the virus may have relatively short-term effects as populations develop resistance after exposure but that, on the other hand, long-lived species with relatively low annual reproductive output may not recover quickly from an outbreak. Sudden oak death, a disease caused by a fungus-like organism, is another recent invader causing locally widespread mortality of a variety of trees, mostly in central California, but with a few in southern Oregon. This disease can kill tanoak and other tree species that provide cover and prey to the northern spotted owl, especially in the southern portions of its range where woodrats are an important part of its diet. Predicting the effects this disease will have on owl habitat is difficult, but the risk is important to recognize. I am not aware of any evidence that the emergence of these new threats is a direct consequence of the Plan. Other potential risks, over which federal land managers have little control, include global warming and the rate of loss of owl habitat on nonfederal lands.

Sources of Uncertainty

Habitat status and trend—

One important accomplishment of the owl effectiveness monitoring program was production of a rangewide map of northern spotted owl habitat. Until this effort, no wall-to-wall coverage was available; existing maps covered only federal land and were assembled from a variety of sources, including satellite imagery, professional judgment from local biologists, and other sources. The current map provides, for the first time, a consistent portrayal of the amount and distribution of owl habitat over the Plan area's full extent. The data were not ideal: there were differences in vegetation mapping between California (Classification and Assessment with Landsat of Visible Ecological Groupings [CALVEG] system) and Oregon/Washington (which was based on the Interagency Vegetation Mapping Project [IVMP] system); the two map products had to be reconciled, and this led to compromises and some degradation of quality. In spite of these difficulties, the resulting map provides a fresh baseline to describe initial conditions and from which to assess changes over the Plan's first 10 years. The map was compiled from information on forest attributes at sites where owls are known to live. The output from the habitat-suitability models is a continuous range of suitability from 0 to 100, with higher values indicating those conditions that are more typical of owl occurrences in the Plan area. Habitat suitability has great utility in describing and ranking owl habitat. For example, in an independent effort McComb and others (2002) built an owl habitat suitability map for the Coast Ranges of Oregon and found that owl occurrence could be predicted with a classification success of 75 percent. Davis and Lint (2005) used a cross-validation process and demonstrated that their habitat suitability maps were highly reliable (see their paper for details). In these cases, owl occurrence, not owl demographic performance, was used in model building. The veracity of this relation between animal occurrence and habitat quality is the subject of much debate (see Van Horne 1983), but I would prefer to have some measure of fitness in relation to forest condition, and much uncertainty exists about what habitat suitability can tell us. In addition, the habitat maps are built on a set of vegetation attributes that were, in turn, derived from models–models relating spectral signatures to forest cover with their own inherent uncertainties.

The habitat suitability maps show a full range of scores, from 0 to 100. To ease communication about results from the map, it is often useful to summarize amount of land area that exceeds some cutpoint for suitability and tallying all sites that exceed that cutpoint. Davis and Lint (2005) chose to summarize areas with scores greater than 41, based on the range generally associated with 90 percent of owl sites, to define a range that is most similar to areas where owls were known to be. This criterion facilitated discussion of amounts of habitat, but other criteria could have been chosen. Any other criterion will result in a different total. The amount of baseline habitat estimated is thus not an absolute quantity but rather depends on the choice of cutpoint. Davis and Lint preferred to tabulate the distribution of acres for the full range of suitability scores. Future monitoring will rely on evaluating changes in the frequency distribution of all suitability scores, not just the acres with the highest scores.

Estimating rates of change in habitat over the past 10 years also carries much uncertainty. Ideally, agency records could be used to map all timber harvest acres, but the records are incomplete. Instead, harvest was estimated by comparing satellite images to detect change. This comparison could detect only regeneration harvest; thinning and other partial harvest that might affect owl habitat could not be mapped. Change detection was also used to locate stand-replacing fires. Again, fire that resulted in partial loss of canopy was more poorly mapped (see Davis and Lint 2005, Moeur and others 2005 for a more thorough discussion). According to Davis and Lint (2005), approximately 13,200 wildfires were recorded on federal land (in the 10 provinces where they mapped owl habitat) from 1994 to 2002. Thus, around 1.7 million acres of federal land (USDA Forest Service [FS], NPS, and BLM) burned within the range of the northern spotted owl. Stand-replacing wildfire data (Moeur and others 2005) suggest that about 230,000 acres were burned with stand-replacing severity, or about 14 percent of the total area burned. The remaining 86 percent of the area burned at lower intensities and severities across all habitat suitabilities, and Davis and Lint were unable to describe the effect this may have had on owl habitat.

Habitat regrowth was estimated by Moeur and others from remeasurement of inventory plots and summarized by tree diameter class. Diameter was only one of several vegetation attributes used to model owl habitat, so the crosswalk between diameter classes and owl suitability classes was highly uncertain. This uncertainty makes inferences about regrowth of owl habitat from transition rates between diameter classes problematic. Davis and Lint (2005) found a strong correlation between stand age and habitat suitability score. They found that suitability scores >40 can be achieved in stands as young as 30 years in the Coast Range of Oregon and 50 years in Oregon western Cascades. Thus, habitat suitability scores >40 can be achieved in older clearcut harvest plantations. Irwin and others (2000) documented owl nesting in stands as young as 45 years in western Cascades of Oregon. This probably accounts for some of the 41 percent of habitat on nonfederal land, which is likely at this lower end of the suitability scale.

Habitat conditions were expected to improve over time as currently unsuitable forest matures and gains attributes to support nesting, roosting, and foraging behavior of the owl. A high potential exists for loss of habitat, especially in the drier portions of the owl's range (but to varying extent throughout the owl range), because of the risk of uncharacteristically large and severe wildfires. Whether appropriate fuel treatment activities will be done and whether such actions will successfully reduce risk of loss of habitat is highly uncertain.

Population status and trends—
Estimates of northern spotted owl population trends were based on a sample of over 10,000 marked owls captured in study areas that encompassed more than 12 percent of the owl's range. Because of this robust sample, estimates of survival, fecundity, and population change were quite precise. I have confidence that the estimates reflect true population trends from 1990 to 2003, but I am not confident in extending these trends into the future. Doing so requires the assumption that vital rates over future years do not change from those observed to date. This assumption is unlikely to hold because habitat conditions will change over time, and because emerging threats such as the barred owl, West Nile Virus, and sudden oak death may also alter these rates. So will climate change: both short-term (changes caused by the Pacific Decadal Oscillation) and long-term changes could have direct and indirect effects on the owl and its prey, increasing uncertainty of population projections.

Are Plan Assumptions Still Valid?

A fundamental Plan assumption was that large, contiguous blocks of habitat are necessary to support a viable population of owls. The reserve system was designed to support large populations of owls, and reserves were spaced close enough to permit recolonization after local disturbance. The size and spacing of these reserves was thus designed to reduce risk of long-term extirpation. The basic science behind this design has not changed: no new evidence suggests that large blocks of habitat are not critical to the persistence of the owl. Large blocks of habitat, while necessary, may not be sufficient to sustain owl numbers if owl mortality rates increase because of the barred owl and other emerging threats. I also note that large blocks of habitat do not always equate to contiguous blocks of old forest. In southern portions of the owl's range, where woodrats are a primary prey, foraging habitat includes brushy cutover or burned areas that support prey. In these areas, large blocks of habitat are a mixture of old forest in juxtaposition with patches of shrub and small tree cover (Olson and others 2004). The importance of this type of habitat was recognized in the Plan, but much uncertainty exists in how much of it will be retained over the long term in large reserves.

The Plan also assumed that land areas between large reserves, the matrix (including riparian reserves along permanent and intermittent streams), would function primarily to support owl dispersal. In practice, more owl habitat is in the matrix than was expected in the Plan. Timber harvesting has been reduced from the expected rate, and there are legal challenges, reduced industry capacity, and low support for cutting older forest in the matrix, resulting in a likely delay in decline of owls using habitat in matrix lands. Silvicultural treatments were assumed to be implemented to reduce fuel and manage risk of stand-replacing fire in dry portions of the owl's range. Such treatments were not done to the extent that may be required and, as a result, the risk of catastrophic loss of habitat in affected reserves may be greater than was assumed in the Plan's design in these areas (see chapter 6). I reiterate, though, that the redundancy built into the Plan through multiple reserves serves as a strong buffer against such losses.

Marbled Murrelet

The marbled murrelet is a small seabird of the family Alcidae whose summer distribution along the Pacific Coast of North America extends from the Aleutian Islands of Alaska to Santa Cruz, California. It forages primarily on small fish in the near-shore (0 to 2 miles) marine environment. Unlike other alcids, which nest in colonies on the ground or in burrows at the marine-terrestrial interface, marbled murrelets nest solitarily and most often in large trees in coniferous forests, traveling up to 50 miles inland to reach suitable habitat (most often <25 miles). Because marbled murrelets depend on marine conditions for foraging and resting and on forests for nesting, both marine and forest conditions can limit murrelet numbers. Because of population declines attributed to loss of mature and old-growth forest from harvesting, low recruitment of young, and mortality at sea, this species was federally listed as threatened in Washington, Oregon, and California in 1992 (USFWS 1997) and listed as threatened in British Columbia (Rodway 1990). Because of the murrelet's association with late-successional and old-growth forests and because of its listed status, conservation of the marbled murrelet was an explicit goal in the design of the Plan.

The Plan is conservative about marbled murrelet habitat. The system of reserves was not designed, as it was for the northern spotted owl, with specific goals for the number and spacing of clusters of birds. Rather, the system of congressionally reserved lands and late-successional reserves would encompass a high proportion (about 2.0 million acres of existing murrelet nesting habitat out of a total of 2.6 million acres) of habitat thought to exist on federal land. In addition, murrelet surveys would be conducted before harvest on any other land in the murrelet range. If a survey showed likely nesting, then all contiguous existing and recruitment habitat (defined as stands that could become nesting habitat within 25 years) within a 0.5-mile radius would be protected. These occupied sites became small reserves, denoted as LSR3, and would be managed to retain and restore nesting habitat.

What Was Expected Under the Plan?

The stated objective of the Plan was to maintain or restore, nesting habitat conditions that would provide for viability of murrelet populations, well-distributed along their current range on federal lands (FEMAT 1993: iv). The expectation was that the Plan "…would eventually provide substantially more suitable habitat for marbled murrelets than currently [that is, at the time the Plan was implemented] exists on federal lands" (USDA and USDI 1994a). The FEMAT used an expert panel to assess the likelihood that habitat on


Bruce G. Marcot

Example of a large limb covered with deep moss in an old-growth Douglas-fir tree. Such substrates are sometimes used for nesting by marbled murrelets in the Coast Range.

federal land would support stationary and well-distributed populations of the marbled murrelet. Following the methods described above for the owl, the murrelet expert panel assigned an 80-percent likelihood that habitat would be of sufficient quality, distribution, and abundance to allow the murrelet population to stabilize, well-distributed across federal land over the next 100 years (outcome A) under option 9, which eventually was adopted (with modifications) as the Plan. The panel assigned a 20-percent likelihood for outcome B, under which habitat would be sufficient to allow the murrelet population to stabilize but with significant gaps in the historical distribution that could cause some limitation in interactions among local populations. The panel assigned no likelihood of outcomes C or D. Thus, the panel's assessment was that the likelihood was high that habitat conditions on federal land would allow the marbled murrelet population to stabilize and be well-distributed throughout its range. In recognition of the major influence of marine conditions on population viability, however, including mortality from oil spills and gill netting, and considering the potentially important role of nonfederal land, the murrelet panel assigned a second set of ratings considering the cumulative effects of all major factors. The murrelet panel concluded that the likelihood that the murrelet population on federal lands would be stationary and well-distributed was between 50 and 75 percent. The higher rating was meant to indicate the degree of protection conferred by habitat conditions on federal lands, assuming all other factors were not limiting; the lower rating from the cumulative effects analysis was an attempt to indicate the greater uncertainty in murrelet persistence given the importance of other factors beyond federal habitat.

Neither FEMAT nor the FSEIS nor the subsequent monitoring plan for the murrelet (Madsen and others 1999) provided quantitative descriptions of expected murrelet population trends or nesting habitat trends over time that could be used to assess Plan performance over the past 10 years. We do have some more qualitative descriptions, however:

- The amount of murrelet nesting habitat has declined over the past 50 years, primarily because of timber harvesting (Perry 1995).
- Murrelet populations are likely to have declined as well, largely in response to loss of nesting habitat (Ralph and others 1995).
- Demographic projection models estimated at the time the Plan was initiated suggested a population decline of 4 to 7 percent per year from 1990 to 1995 (Beissinger 1995).
- Because murrelets have naturally low reproductive rates, population recovery will be slow, on the order of a maximum of 3 percent per year (USFWS 1997).
- No nesting habitat surrounding active murrelet nesting sites will be knowingly destroyed on federal lands.
- Catastrophic and stochastic events that decrease the quality or quantity of nesting habitat would affect nesting habitat at unknown rates.
- Over the long term, the amount of nesting habitat will increase in reserves as unsuitable habitat matures; LSRs will provide large contiguous blocks of nesting habitat with increased interior habitat.
- Rates of nest depredation would decrease as the amount of interior nesting habitat increases in reserves.
- In the short term (<50 years), the availability of nesting habitat may remain stable or decline from losses from fire and other natural disturbances.
- The rate of increase in the amount of nesting habitat will be slow because trees do not develop structures suitable to support nests until they are large and old, often 150 or more years (USDA and USDI 1994a).
- Habitat management on nonfederal land will affect viability of marbled murrelets on federal land.
- Physical and biological processes in the marine environment, which operate at multiple temporal and spatial scales, also affect short- and long-term population trends of the marbled murrelet, independent of nesting habitat quantity or quality.

McShane and others (2004) developed a population model to predict population change in each of five conservation zones composing the Plan area. Their model, which used annual adult survival estimates obtained from detailed mark-recapture studies in British Columbia (the only such data available) and fecundity estimates from observing juveniles at sea or telemetry studies, predicted annual rates of decline varying from 3 to 5 percent per year over the first 20 years of their simulations in murrelet conservation zones 1 through 5.[3] Rates of decline were generally greater going from north (zones 1 and 2) to south (zone 5). These predictions are in line with those of Beissinger (1995). These

[3] These zones are defined in the marbled murrelet recovery plan (USFWS 1997): conservation zone 1 is Puget Sound and Strait of Juan de Fuca in Washington; zone 2 is the outer coast of Washington to the Columbia River; zone 3 is Oregon south from the Columbia to North Bend; zone 4 is North Bend south to Shelter Cove, California; zone 5 is south to San Francisco Bay.

models do not directly account for amount of nesting habitat, and so model projections do not respond to expected habitat trends.

What Has Happened and Did Expectations Differ From Observations?

Baseline habitat—

When the Plan was developed, no consistent map of marbled murrelet nesting habitat was available. For purposes of the Plan, murrelet nesting habitat was assumed to be late-successional forest with much the same characteristics as northern spotted owl habitat. Therefore, the existing map of spotted owl habitat, which was itself a mosaic derived from compilations of local maps based on agency judgment, classified satellite imagery, and existing inventory maps, was constrained to the range of the murrelet and used as a proxy for murrelet nesting habitat. No estimate or map of habitat on nonfederal land was available. The marbled murrelet effectiveness monitoring group developed a new map, by using a consistent vegetation base (based on vegetation data from CALVEG and IVMP, see Moeur and others 2005), across all ownerships throughout the range of the murrelet (Raphael and others 2006). This habitat classification was based on estimates of patch size, conifer cover, quadratic mean tree diameter, canopy structure, slope, aspect, and distance from coast. Raphael and others developed a habitat suitability model in much the same manner as described above for owl habitat. Under this model, habitat suitability ranges along a scale from 0 (least suitable) to 100 (most suitable). Raphael and others used a cutoff of suitability >60 to portray potential nesting habitat in tables and maps. The total amount of potential nesting habitat estimated from this new map was 1.9 million acres on federal land within marbled murrelet zone 1 (the zone closer to the west coast in which most murrelets occur). The estimate of habitat on federal land from the FSEIS was 2.6 million acres in murrelet zones 1 and 2 combined (there was no separate estimate for zone 1 alone). I expected differences in estimates as the new map was derived from a satellite-based suitability model and because Raphael and others defined an upper elevation limit for murrelet nesting, and some nesting habitat considered by the FSEIS may have been above that limit.

About 28 percent of area capable of supporting murrelet habitat is on federally administered land in the murrelet range portion of the Plan area (18.0 million acres of federal and nonfederal habitat-capable land); federal land supports 48 percent of higher-suitability nesting habitat (fig. 7-4) and nonfederal land supports 52 percent (Raphael and others 2006). The contribution from nonfederal land varies: in Washington, 77 percent; in Oregon, 55 percent; and in California, 47 percent. On federal land, about 75 percent of habitat-capable land is in reserved land-use allocations and 81 percent of nesting habitat is in those allocations (fig. 7-5). In Washington, the amount of nesting habitat in reserves is 93 percent; in Oregon, 76 percent; and in California, 71 percent. The Plan seems to have successfully captured most of the existing nesting habitat in the reserve system. The FSEIS estimated that 86 percent of murrelet nesting habitat would be in reserves. The reserve system includes about 63,000 acres of habitat-capable forest in LSR3s, and these small reserves contain about 21,000 acres of suitable habitat. I conclude that the Plan has successfully encompassed a majority of murrelet nesting habitat within its reserve system and that additional occupied habitat outside the large reserves has been designated and reserved.

Habitat losses—

The intent of the Plan was to conserve most of the remaining murrelet nesting habitat and to prevent the subsequent loss of any habitat occupied by nesting birds, wherever that habitat was on federal lands. The amount of habitat was expected to increase over time, but the rate of increase would be very slow and changes might not be observed for many decades. In the meantime, some unoccupied habitat would be lost from timber harvest, and some losses might be caused by wildfire and other disturbances.

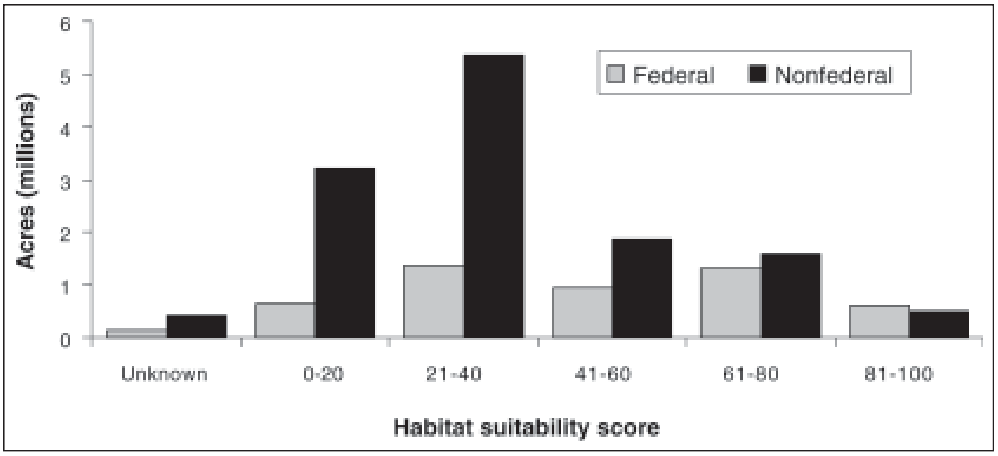

Figure 7-4—Estimated amounts of marbled murrelet nesting habitat (defined by using a gradient of low to high habitat suitability scores) on federal and nonfederal lands within the Plan area (after Raphael and others 2006 tables 9, 10).

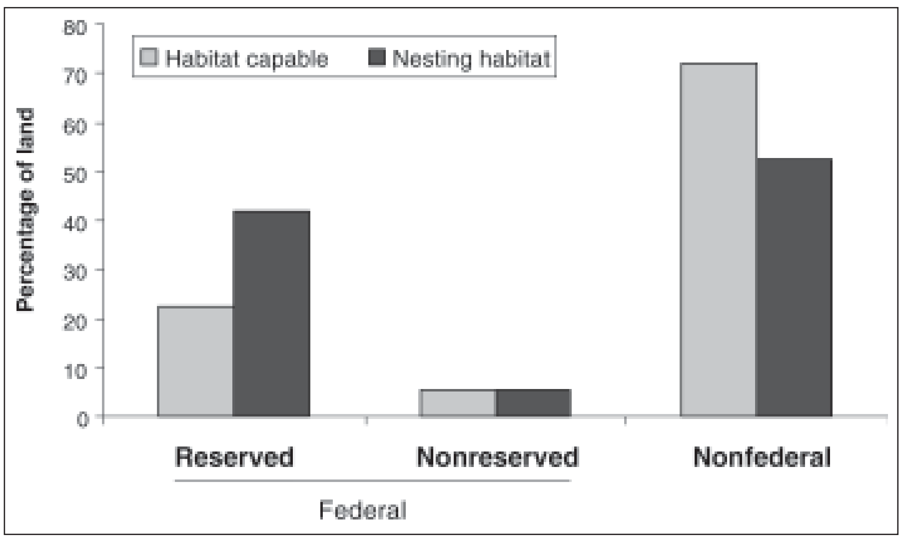

Figure 7-5—Distribution of marbled murrelet nesting habitat (defined by using habitat suitability scores >60) on federal and nonfederal lands compared to percentages of habitat-capable forest land in the Plan area (after Raphael and others 2006 tables 9, 10).

The observed trends are in line with these expectations. Raphael and others (2006), based on analysis of satellite imagery and change detection methods (see Moeur and others 2005) estimated losses of 54,900 acres of nesting habitat on federal land over the past 10 years, mostly from fire, and most of that in one event, the Biscuit Fire. Losses from timber harvest totaled 3,800 acres, 74 percent of which was outside of reserves. Losses to fire and other stand-replacing events totaled 51,000 acres, and 93 percent was in reserves. Total losses represent 2.3 percent of nesting habitat over the 10 years, or a loss of 0.23 percent per year. Rates of loss have been much greater on nonfederal land: Raphael and others (2006) estimated that over 150,000 acres of nesting habitat, or about 10 percent, has been lost because of timber harvest over the past 10 years.

As part of the status review for the murrelet, McShane and others (2004), compiled agency records (almost all from federal lands) to estimate losses to harvest and fire, and developed an independent estimate of amounts and losses of murrelet nesting habitat. McShane and others estimated total losses from 1992 to 2003 of 22,400 acres, 5,400 from harvest and 17,000 from fire and windstorms. They estimated a total of 2.2 million acres of suitable habitat on all ownerships; losses represent 1.1 percent of that amount, or 0.11 percent per year. The Raphael and others and McShane and others estimates apply to all habitat, whether occupied or not. I have no estimate of the loss of occupied habitat, so I cannot say whether the Plan objective of no loss of occupied habitat from timber harvest was met. Raphael and others and McShane and others differ because of the sources of data used and the records available in each case. Because the Raphael and others analysis is a more thorough evaluation of the entire murrelet range and uses change-detection methods, I believe it is more complete than the McShane and others data.

Habitat increases—
One Plan expectation was a gradual increase in the amount of suitable habitat as forests mature. Some evidence showed that the amount of forest with large (>20 in)-diameter trees has increased over the first 10 years of the Plan, based on analyses of inventory plots on national forest land in the murrelet range (Moeur 2005). Moeur tallied the distribution of plots by mean tree diameter during two remeasurement cycles, averaging 3.8 years apart. She estimated a net annual increase of the largest tree diameter class (>30 in) of 0.4 percent per year over the past decade. I do not know how much of this increase represents suitable nesting habitat. Certainly, not all of it does, because nesting platforms (the key attribute defining suitable nesting habitat) do not generally form until trees reach diameters of 40 inches or more (Raphael 2004). Further work will be needed to verify how much of the increase actually has attributes of suitable habitat.

Population trends—
Murrelet populations were thought to be declining at the start of the Plan, and I expected these declines to continue until habitat recovered from previous losses. The marbled murrelet effectiveness monitoring group designed a coordinated sampling protocol and obtained population estimates starting in 2000; yearly estimates have continued and are reported up to year 2003 (Miller and others 2006). The total estimated population has averaged about 18,200 birds over the 4 years of survey. Estimates vary by conservation zone (fig. 7-6), with the largest population in zone 1 (Puget Sound, Washington) and the smallest in zone 5 (north-central California). Population size did not show a downward trend during the 4 years of study; the numbers were relatively stationary. Given the confidence intervals around the mean population estimates each year, Miller and others (2006) computed that 7 years of survey would be required to detect a 5-percent annual decline with a power of 80 percent. I conclude little evidence exists of the expected decline in murrelet numbers, but I recognize that more years of survey will be needed to confirm this conclusion with greater confidence.

Extent to Which Differences Were Caused by the Plan

Habitat status and trend—
The Plan played a pivotal role in the fate of marbled murrelet habitat on federal land. The Plan has been highly successful in conserving existing murrelet nesting habitat, and little habitat has been lost from timber harvest. Some loss of habitat, especially in reserves, was caused by fire. Loss of murrelet habitat from catastrophic events will always be a risk, and such losses were expected. The Plan has less control over risk to such losses, except to the extent that active management in fire-prone areas might reduce risk by managing fuel. One caution: managing forest cover to reduce fire risk could also lead to

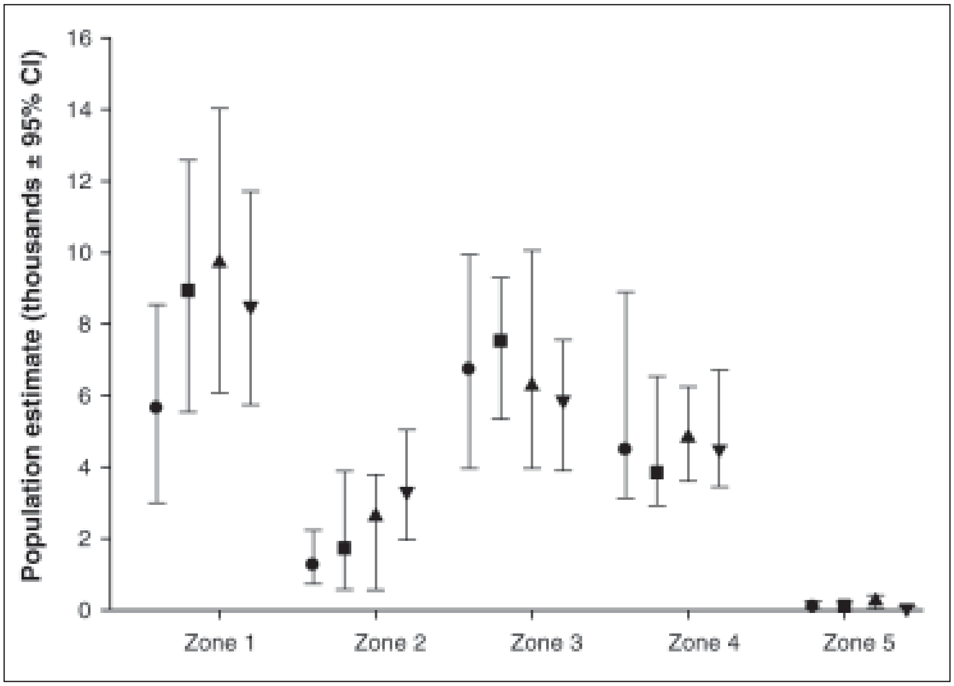

Figure 7-6—Marbled murrelet population estimates and 95 percent confidence intervals by zone (conservation zones per USFWS 1997) and year in the area of the Plan (from Miller and others 2006).

better habitat for corvids (nest predators); silvicultural practices may need to be fine tuned to ensure they do not inadvertently impair nesting success of murrelets through increasing the rate of nest depredation.

The fate of habitat on nonfederal land is beyond the scope of the Plan, and 72 percent of habitat-capable forest is in state or private ownership with 52 percent of murrelet nesting habitat on these nonfederal lands. The rate of harvest on nonfederal land (1.2 percent per year) has been far more rapid than that on federal land (0.1 percent per year).

Raphael and others (2006) found evidence of increase in the area occupied by forests with large trees (>30 in diameter) on federal lands. This increase is consistent with Plan expectations; if any of this increase contributes additional nesting habitat, however, it is sooner than was expected. The large reserves included recruitment habitat at the start of the Plan, and some of that habitat may not require many years to meet the attributes of suitable nesting habitat.

Population trends—
Marbled murrelet populations are affected by a variety of factors, only some of which are under the Plan's direct influence. The Plan most directly affects populations through its provisions for conservation and restoration of nesting habitat, but even then the Plan's influence extends only to the federal land. The Plan has no influence on marine conditions (including marine food sources) or sources of mortality at sea such as oil spills and gill netting. Therefore, it will be more difficult to relate changes in marbled murrelet populations to land management under the Plan. With the Plan conserving habitat exactly as expected, murrelet populations could still fall because of adverse marine conditions or because of habitat loss on nonfederal land. Despite this uncertainty, evidence suggests that inland habitat conditions are the major driver setting murrelet population size. This point is illustrated in figure 7-7, which shows a very strong correlation with the total amount of habitat and size of adjacent murrelet population

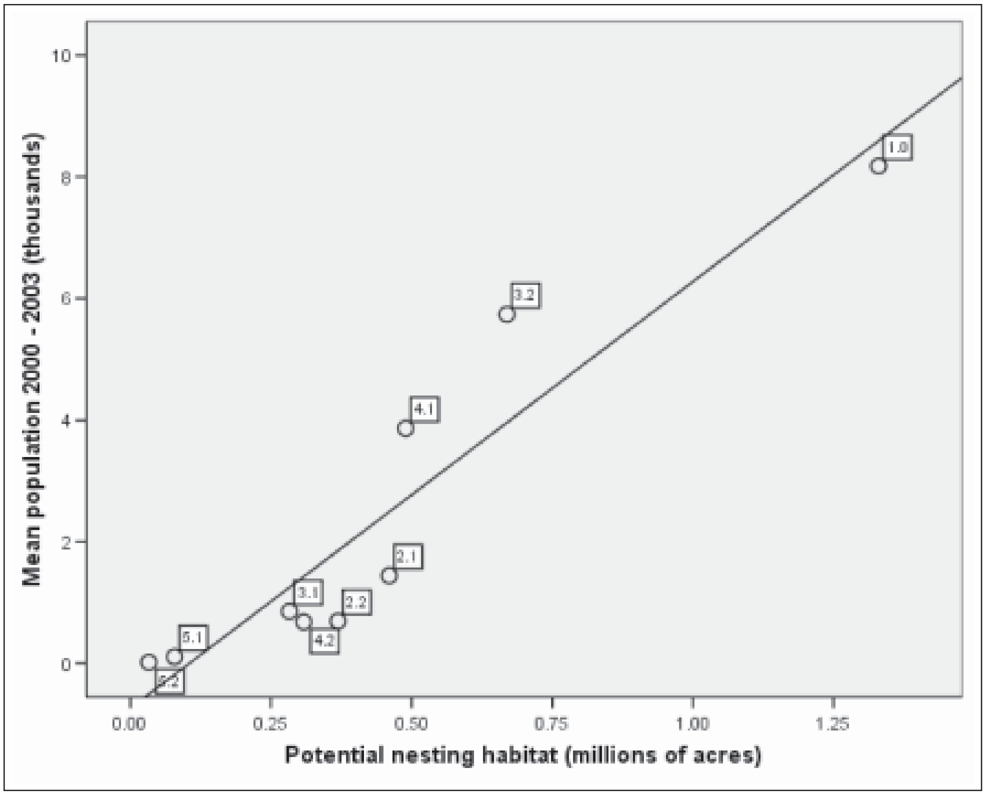

Figure 7-7—Comparisons of estimated mean murrelet population size with potential murrelet nesting habitat (defined by using habitat suitability scores >60) by sampling strata within conservation zones (for example, 2.1 denotes conservation zone 2, stratum 1). Zones run from north (zone 1) to south (zone 5). See Miller and others (2006) for a description of methods used to estimate murrelet population size. After Raphael and others (2006).

for segments of the murrelet range. Habitat seems to be the primary driver, with marine conditions possibly contributing to residual variation along the coast.

Sources of Uncertainty

Habitat status and trend—

Sources of uncertainty in estimating the amount and distribution of nesting habitat of the marbled murrelet are very similar to those cited for the owl. But one additional source is unique to the marbled murrelet. Because murrelet nesting behavior is so cryptic, biologists have found very few actual nests of the species. Habitat models for the spotted owl were built from attributes of a large sample of known owl nest sites. For the murrelet, biologists rely on locations of “occupied behaviors” to infer nesting activity. Occupied behaviors are observations of murrelets flying into the canopy or circling very close above the canopy. These behaviors are presumed to be associated with nesting, but nesting is rarely verified. Thus, sites in which occupied behaviors are observed may not be true nest sites. To the extent that false positives are included in the murrelet database used to build models, these models may be less accurate than if all locations were based on verified nests. Furthermore, occupied behaviors are not observed at every visit to a site; a finite likelihood exists of failing to detect occupied behaviors even if the site is occupied. A specific protocol (Evans Mack and others 2003) sets the numbers of visits required to have a high likelihood (set at 0.95) of observing occupied behavior at an occupied site. Under this protocol, a 5-percent chance of failing to detect occupied behavior exists, so a small number of sites might be mistakenly classified as unoccupied and released for timber harvest. A more reliable modeling solution would be to conduct intensive research to identify known nest sites and then to build models from training sites that represent actual murrelet nests.

Uncertainty also exists in the geographic distribution of the marbled murrelet. The FEMAT designated two zones: zone 1 formed the area closer to the marine environment, and zone 2 was an outer area along the eastern fringe of the species' range. Populations were assumed to be more abundant in zone 1. More recent surveys have led to suggestions for substantial local contractions of zone 2, and possibly even zone 1, especially in northern California and southern Oregon (Alegria and others 2002, Hunter and others 1998, Schmidt and others 2000). Agencies in those areas have redefined the eastern boundary, where surveys for murrelets are required prior to timber harvest, bringing it farther to the west to match survey results. This revised boundary has not been formally implemented in the Plan databases; to date this revision only applies to survey requirements. This strategy adds uncertainty in the calculation status of habitat to the extent that acres classified as habitat may actually fall outside the revised species range.

Population status and trends—

We have only 4 years of murrelet data from which to assess population trend. Error estimates around each year's population estimate are fairly large, and it will take 7 or more years before one can reliably say whether the population is stationary, increasing, or decreasing. The data collected so far seem to indicate a relatively stationary population, which is at odds with the prediction, calculated from demographic models that predict the population should be declining (McShane and others 2004). A major source of uncertainty is whether the murrelet population is closed or open. That is, existing population models assume there is little or no recruitment of either adults or juveniles from outside the study population. The local population may be declining, but populations may be being subsidized by immigrants, perhaps from Alaska or British Columbia where the birds are more numerous. Recruitment of birds from outside the local range has been proposed as the most likely explanation for observed stationary murrelet population trends in central California, despite models that suggest a decline (Peery 2004).

Future population trends are also difficult to predict because of uncertainties in the timing and extent of risk factors. Catastrophic loss of habitat from uncharacteristically severe wildfire is an ever-present risk in portions of the range. Populations at sea are subject to risk from large oil spills. Changes in ocean currents can have profound effects on forage fish leading to starvation or breeding inhibition, as has been observed in other seabird populations (for example, Montevecchi and Myers 1997). Emerging threats exist from the West Nile Virus, which could cause direct mortality to nesting birds, but the virus could also have indirect beneficial effects. The virus is documented to kill jays, crows, and ravens, and mortality of these birds may increase nest success of murrelets by reducing nest depredation.

Are Plan Assumptions Still Valid?

The fundamental assumption of the Plan was that the rate of loss of murrelet habitat in reserves would slow or stop and that unsuitable habitat would recover. Available data support this assumption and show that rates of loss are low and that forest stands in reserves are on a trajectory toward higher habitat suitability. Conservation and restoration of murrelet nesting habitat is essential to population viability of the species.

Although federal habitat protection is essential to murrelet viability, it may not be sufficient, given the cumulative effects of other influences on population viability. Scientists assumed that murrelet viability depended on a variety of factors, many of which are not under the control or influence of the Plan. This assumption still holds. Habitat loss on nonfederal land, marine conditions, and threats from disease, oil spills, and gill-netting could reduce the likelihood of population viability despite the habitat protections built into the Plan.

The requirement for preproject surveys was assumed to prevent the loss of any occupied sites from timber harvest. I was not able to test this assumption, because I have no way to assess whether sites were classified as unoccupied when they might actually have been occupied. I can say that sites classified as occupied were, in fact, set aside and managed as reserves.

Past timber harvest was assumed to have lingering effects on murrelet carrying capacity and nesting success. I am aware of no new data to challenge this assumption. Recent research shows that murrelet population size is reduced as habitat is lost, and that birds do not pack into remaining suitable habitat (Burger 2001, Raphael and others 2002a). Predator densities and rates of nest depredation are higher in areas with a variety of tree ages, so nest success is reduced in areas intermixed with young tree/brush habitats (Luginbuhl and others 2001).

A major premise of the Plan is that large reserves will support more murrelets, eventually leading to stationary or increasing populations. Nest depredation seems to be a major limiting factor on marbled murrelet populations. Over half of the known murrelet nests whose fate has been determined failed because eggs or chicks were lost to predators, primarily jays, crows, and ravens (Manley and Nelson 1999). Recent research suggests that predator numbers are high in old-growth forests, such as those expected to develop in Plan reserves (Marzluff and others 2000, Raphael and others 2002b). Habitat fragmentation was assumed to decline as young patches within reserves matured, creating more contiguous canopy cover, and the rates of nest predation would decrease as forests became less fragmented. More recent evidence suggests that rates of nest depredation may be just as high in contiguous forest as in fragmented stands. Murrelet populations may not grow at the rate predicted from recovery of nesting habitat in reserves because nest depredation could suppress successful reproduction. We lack understanding of the full suite of factors that affect nest success, which increases uncertainty about the relations between amounts of habitat and murrelet populations.

Summary Considerations

Importance of Considering Cumulative Effects

Wildlife population trends reflect the cumulative effects of multiple interacting factors. Habitat condition on federal land is but one of those factors, albeit the one over which the Plan has most direct influence. Monitoring of both habitat trends and population trends is of value: monitoring habitat trends tells managers how well the Plan is meeting its primary objectives; monitoring population trends tells managers if the Plan is having the desired effect. Ideally, population trend will track habitat trend, but we may observe diverging trends, as we have in the case of the northern spotted owl. In such cases, we can dig deeper to discover whether our understanding of habitat relationships is mistaken or whether other, perhaps unmeasured, factors are driving population trends. What we can say with confidence is that the amount of habitat will set the carrying capacity for wildlife populations. Carrying capacity is a measure of the potential population size that can be supported by a given amount and distribution of suitable habitat. The actual population may be lower than the carrying capacity from a variety of other factors such as hostile weather, interactions with other species, habitat conditions outside of the planning area, disease, or other factors that might depress a population. Observing a declining population in the face of habitat conservation does not mean habitat is not important or that habitat conservation is not important. It means we have to look at options to manage some of the other factors that might be driving the population trend. Until we have more robust models of wildlife habitat relationships, including these other factors, it will be essential to continue monitoring both population and habitat trends to evaluate how well the Plan is meeting its intended objectives.

Efficacy of Large Reserves for Conservation

A central tenet of the Plan was that the system of large, late-successional reserves would largely suffice to provide for species and biodiversity components associated with late-successional and old-growth forest ecosystems. I have found that, to an extent, this is likely true. However, the degree to which LSRs–along with the set of other Plan land allocations (for example, riparian reserves in matrix lands)–suffice differs considerably by species. It also likely differs by the specific locations chosen for the LSRs–such as whether they happen to intersect sites of particularly suitable habitat, and if they happen to contain microenvironmental conditions and specific habitat elements used and selected by those species. Older forest and habitat are not synonymous. For example, I described the importance of shrubby, early-seral vegetation in juxtaposition with older forest as foraging habitat for the northern spotted owl in the southern part of the owl range. Reserves may not function to support owls in the future if this shrubby component is not maintained as forests mature. Having large reserves, in which large expanses of old forest provide nesting habitat for owls and murrelets, and in which fire and other natural disturbances can create desired early-seral conditions for owl foraging habitat, remains a critical strategy.

One of the management dilemmas is that habitat conditions differ among species. Creating shrubby foraging habitat will be good for the northern spotted owl, but such habitat will also be good for jays and crows, which depredate nests of the marbled murrelet. In this case, what is good for the owl may be bad for the murrelet.

Efficacy of Smaller Designated Reserves

The designation of smaller reserves around owl activity centers (LSR4s) and around occupied murrelet sites (LSR3s) requires continuing survey effort to locate the birds (in the case of the LSR3s), and reduces opportunities for timber harvest in the matrix. I believe an effort could be undertaken to reevaluate the efficacy of these smaller reserves in light of current habitat information and population trends. I suspect it would be difficult to justify removing the provisions for spotted owls in light of their continuing population decline. At a future date, if population trends appear more stationary, these reserve designations could be revised. In the case of the murrelet, there may be an earlier opportunity to revise the LSR3 designations if population trends remain stationary and habitat continues to increase in the larger reserves. A note of caution: although the LSR3s and LSR4s were established around murrelet and owl activity centers, they were also placed on the landscape to provide smaller refugia for other species associated with older forest, not exclusively to support murrelets and owls. The owl activity centers were convenient objects to use in directing the field offices to place small blocks of older forest on the landscape. Even when they are no longer occupied by spotted owls, they still remain as protected patches of older forest, so regardless of their efficacy for owls they would still have conservation value. In essence, the LSR3s and LSR4s were built around owls and murrelets, but their function extends beyond those two species.

The Plan remains the boldest effort ever undertaken by federal agencies to meet large-scale biodiversity objectives. As part of this broad biodiversity objective, the Plan had an objective to provide habitat conditions that would support viable populations of the owl and the murrelet. In the short term, the objective for owls and murrelets was to conserve much of the best remaining habitat. The Plan has been quite successful in meeting this objective. The Plan also has a long-term objective: create a system of reserves containing desired sizes and distributions of large blocks of suitable habitat. Evidence suggests that habitat trends are on course toward this objective, but many more decades will be needed to judge the Plan's success. I have shown that the Plan has been remarkably successful in conserving habitat over its first 10 years of implementation, but much work remains. Owl numbers continue to decline. Time will tell if the Plan will fully succeed.

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Continue

Chapter 8: Conservation of Other Species Associated With Older Forest Conditions

Bruce G. Marcot and Randy Molina

Introduction

This chapter presents information on expectations and outcomes for species closely associated with older (late-successional and old-growth) forests (hereafter referred to as LSOG species), other than fish (see chapter 9) and northern spotted owls (see appendix for scientific names) and marbled murrelets (see chapter 7), that were considered as part of the Northwest Forest Plan (the Plan). Many of the LSOG species are rare and little known, and include fungi, lichens, bryophytes (mosses and liverworts), vascular plants, invertebrates (mostly mollusks, and selected species groups of arthropods), and a few vertebrates. We also review the Survey and Manage (SM) program established under the Plan to provide for rare and poorly known LSOG species.

In this chapter we discuss species outcomes and program outcomes pertaining to what was expected under the Plan, what occurred, and if there were differences between expectations and observations; the extent to which differences were caused by the Plan; and if the Plan assumptions are still valid. We summarize lessons to learn both in terms of conservation concepts and program activities over the last decade.

Biodiversity Was the Umbrella; Species Became the Focus

The Plan was instituted as an ecosystem management plan to attend, in part, to biological diversity. To this end, the Plan was expected to provide for functional LSOG forest ecosystems, including all associated species and all components of biodiversity. Biodiversity is generally defined (for example, DeLong 1996, Raven 1994) as the variety of life and its processes, and includes structure, composition, and function of multiple levels of biological organization ranging from genes through population, species, functional groups, communities, and ecosystems (Noss 1990). Under the Plan, however, the focus on biodiversity narrowed to addressing mainly the composition, amount, dispersion, and dynamics of old forest vegetation communities (see chapter 6) and the presence and persistence of specific species, namely salmonids, spotted owls, marbled murrelets, and a set of other LSOG-associated species.

In this chapter we mostly trace the recent history of species-level conservation and associated programs of work under the Plan. In the next sections we review the recent history of LSOG species assessments and the Plan provisions for conservation of LSOG species. However, at the end of the chapter we will return to the broader vision of biodiversity conservation, where we review recent trends in conservation biology and how they may pertain to lessons learned under the past decade of the Plan.

A Brief History of LSOG Species Assessments Under FEMAT and the Northwest Forest Plan

To help set the stage for much of the rest of this chapter, following is a brief summary of the rather complicated history of the assessments and administrative programs under the Plan pertaining to management of LSOG-associated species (fig. 8-1).

The Forest Ecosystem Management Assessment Team (FEMAT 1993) initially evaluated a list of 1,120 LSOG-associated species under option 9; this option, with some changes, became the basis for the Northwest Forest Plan under the 1994 final supplemental environmental impact statement (FSEIS) (USDA and USDI 1994a). The 1994 FSEIS then identified 4 sets of criteria ("screens") by which the 1,120 LSOG species were further evaluated to determine

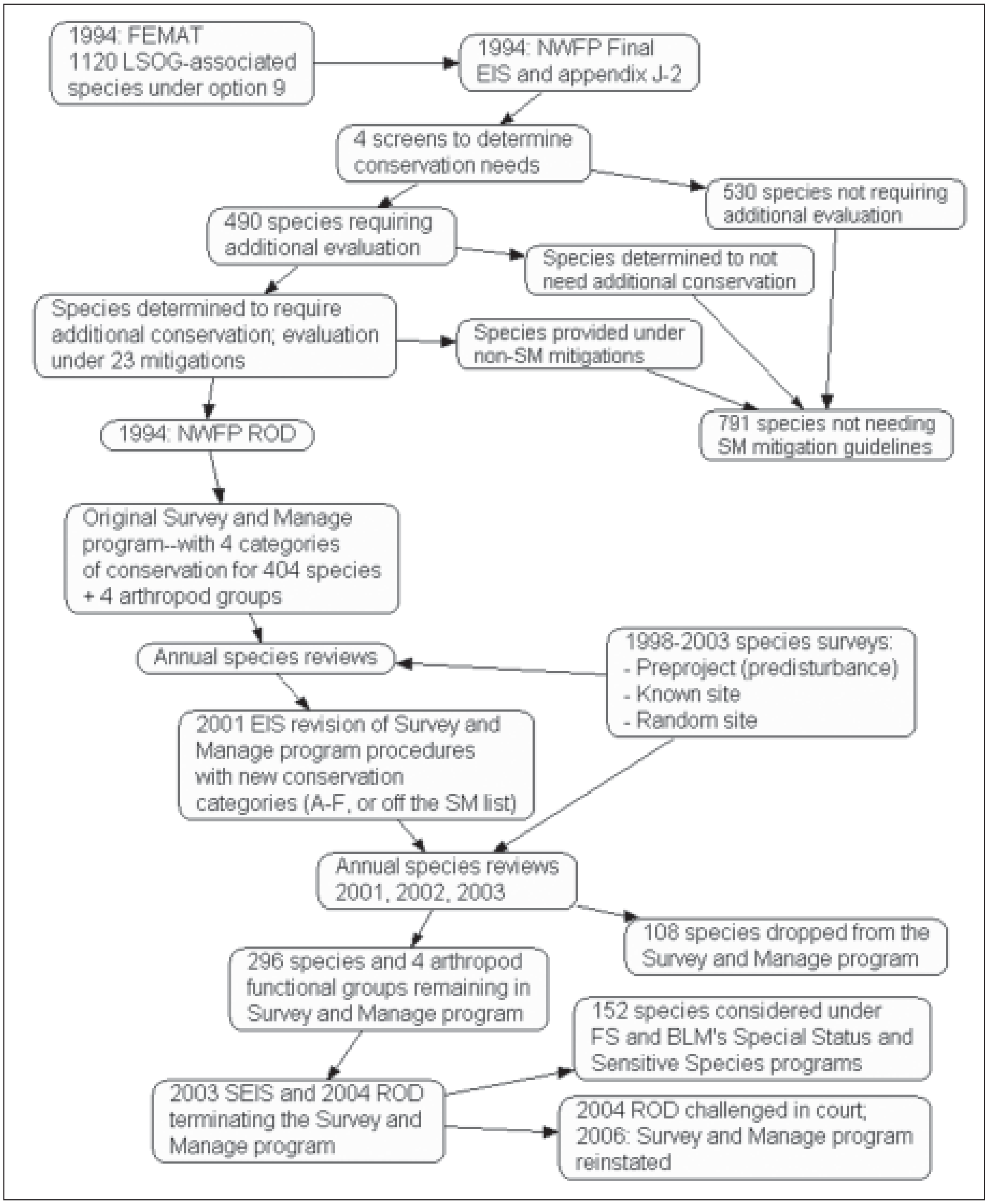


Figure 8-1—Lineage of administrative programs and National Environmental Policy Act environmental impact statement (EIS) and record of decision (ROD) documents under the Forest Ecosystem Management Assessment Team (FEMAT), the Plan (NWFP), and the Plan's Survey and Manage program (SM), addressing species associated with late-successional and old-growth (LSOG) forests on Forest Service (FS) and Bureau of Land Management (BLM) administered lands.

their appropriate conservation categories. The screens resulted in 791 of these species not being carried forward under mitigation for their conservation in addition to the Plan provisions, whereas the remainder of the species were determined to entail additional conservation and evaluation under further mitigation.

A set of 23 mitigations was evaluated in the 1994 SEIS (USDA and USDI 1994a) and 8 of these were adopted in the record decision (ROD) (USDA and USDI 1994b). One of the mitigations was the original SM species mitigation, which categorized each of 404[1] individual species and 4 arthropod species groups[2] according to four conservation classes, each class having a set of mitigation standards and guidelines. Standards and guidelines consisted of employing a variety of survey approaches (preproject or predisturbance, extensive, and general regional surveys) along with guidelines to protect (manage) known sites and to select high-priority sites for management. New information gained from surveys would address the uncertainty regarding species persistence concerns and would inform decisions.

In 2000 and 2001, a new FSEIS and ROD were issued (USDA and USDI 2000, 2001) to revise the SM species program procedures to specify greater details on conducting annual species reviews (ASRs), species management requirements, the use of strategic surveys, and an expanded classification of six species conservation categories. Subsequent ASRs held 2001-2003 used the new (2001) survey guidelines and evaluation procedures, and resulted in 108 SM species being dropped from the SM program because of the new data and evaluations. This left 296 individual species and 4 arthropod species groups remaining in the SM program. The SM program was removed after issuance of an FSEIS and its associated ROD in 2004 (USDA and USDI 2004a, 2004b[3]), which moved 152 of the remaining 296 SM species to the USDA Forest Service (FS) Sensitive Species Program and the USDI Bureau of Land Management (BLM) Special Status Species Program. In January, 2006, the court ruled that the SM program be reinstated according to the 2001 ROD.

A Summary of Northwest Forest Plan Provisions for LSOG Species

The Plan, as guided by the 1994 (and later, supplemented to 2001) ROD, contained several provisions for conservation of LSOG species. These included the delineation of late-successional reserves (LSRs) designed to accommodate populations of northern spotted owls, marbled murrelets, LSOG species, and other objectives; the delineation and protection of known sites of SM species found outside the LSRs in “mini” reserves (dubbed LSR3s in the Plan); delineation and protection of high-priority sites of selected SM species; and the expectation that some LSOG species locations and habitats would be provided for by other measures to protect older forest components such as the Aquatic Conservation Strategy and riparian reserves. In general, the major land allocations under the Plan were expected to provide habitat in appropriate amounts and distribution to support most LSOG-associated species.

What Was Expected Under The Northwest Forest Plan?

Expectations of Species Outcomes

Persistence of LSOG species and biodiversity— Under the Plan, the management guidelines and land allocations, particularly the LSRs, were expected to provide for persistence of most native LSOG-associated species

[1] In actuality, there were only 403 species, as the name of one species was inadvertently included twice (Holmes 2005). For the sake of consistency with the 1994 ROD, however, we will use the 404 figure here.

[2] The four arthropod species groups are canopy herbivores (south range of Plan area), coarse wood chewers (south range), litter- and soil-dwelling species (south range), and understory forest gap herbivores (USDA and USDI 1994b: C-1).

Although abandoned in 2004 through a SEIS and new ROD, the Survey and Manage program was reinstated in 2005 by court order following lawsuits brought by environmental groups. A new SEIS is currently in progress.

(and all other elements of LSOG biodiversity). This specifically included the 791 species not requiring mitigations of the SM program but that were expected to be provided for by the LSRs and other mitigations specified in the 1994 ROD (USDA and USDI 1994b), and the 404 individual rare and little-known species and 4 arthropod species groups that would require additional consideration and protection under the SM program. The Plan did not specifically define either "rare" or "little-known" in identifying these lists of species. As necessary, species- or taxon-specific assessments would be conducted to help determine where and what additional management guidelines would pertain to ensuring persistence of species and biodiversity elements not otherwise provided for.

Reduction of uncertainty and avoidance of listing—
For the 404 individual species and 4 arthropod species groups, it was generally expected that knowledge gained from SM program surveys, together with immediate protection of known sites, would help reduce scientific uncertainty, reduce risk of their extirpation, and increase overall chances for their persistence within the Plan area. Such mitigation activities under the SM program would be expected to stave off potential federal listing of LSOG-associated species.

Expectations of Program Outcomes

Adaptive management framework—
Expectations under the 1994 ROD (USDA and USDI 1994b) included that the SM program would provide an adaptive management framework for collecting new information on the 404 species and 4 arthropod species groups, for the purpose of evaluating and revising their conservation management status as deemed appropriate to ensure their persistence; and that the SM program would be a practical and economically efficient means to this end, with adequate resources to accomplish its objectives. It was also expected that sites would be protected for those species of high persistence concern, and that management recommendations would be developed to guide site management, which would entail protection on the order of tens of acres (with some exceptions) and some management treatments (for example, prescribed fire for some vascular plants). The agencies would develop an interagency geographic information system (GIS) database to house the information for analysis.

Survey protocols and species surveys—
It was further expected that effective survey protocols would be developed. The 1994 ROD (USDA and USDI 1994b) required surveys for amphibians and the red tree vole to begin by 1997 and for all other "strategy 2" species (species for which predisturbance surveys were to be conducted) by 1999, and that protocols would be prioritized based on species risk level.

Predisturbance surveys would be conducted to avoid loss of sites for some species. Such surveys would start at the watershed analysis level to identify likely species based on habitat. For species for which predisturbance surveys were not required, likely sites would be identified at the individual project scale based on likely range and habitats. Multispecies surveys would be used as possible, and survey protocols and site management would be incorporated into interagency conservation strategies as part of ongoing planning efforts. This would include identifying high-priority sites for protection. Broad-scale (general regional) surveys would be implemented by 1996 and completed within 10 years, and major areas of scientific uncertainty on most species resolved during that period. The 2001 ROD noted that statistically-based "strategic surveys" (Molina and others 2003), together with other approaches including research and habitat modeling, would replace the previous extensive and general regional surveys, to provide more reliable scientific data on species rarity and habitat associations.

Changes in activities and no adverse effect on probable sale quantity—
It was also expected that changes of management activities under the SM program would include evaluating and

potentially altering schedules for conducting surveys, moving species from one category to another, and dropping the SM mitigation for any species whose status is determined to be more secure than originally projected. The SM program would be expected to not adversely affect probable timber sale quantity (PSQ) beyond levels noted in the FSEIS (USDA and USDI 1994a).

Annual species reviews—
As summarized above (also see fig. 8-1), the 2000 FSEIS and 2001 ROD (USDA and USDI 2000, 2001) instituted a revised SM program, which was expected to provide clarity to ASRs as an adaptive evaluation process. It was expected that the data-gathering and ASR procedures would likely result in removing some species from the SM species list, and that National Environmental Policy Act documentation would not be made for decisions made under the ASR process. The ASRs would apply criteria for species' persistence, rarity, and association with LSOG forests and reserves to judge the category of SM mitigation for each species. The 2000 FSEIS and 2001 ROD also provided criteria for potentially adding species to the SM list.

Biodiversity and rare species monitoring—
The 1994 ROD (USDA and USDI 1994b: E-6, E-8–E-11) explicitly called for effectiveness and validation monitoring of biodiversity and rare species. The 1994 ROD defined effectiveness monitoring as "evaluating if application of the management plan achieved the desired goals, and if the objectives of these standards and guidelines were met." It specified that "Success may be measured against the standard of desired future condition… Effectiveness monitoring will be undertaken at a variety of reference sites in geographically and ecologically similar areas. These sites will be located on a number of different scales…" (USDA and USDI 1994b: E-6).

The 1994 ROD specified effectiveness monitoring of biological diversity and late-successional and old-growth forest ecosystems including "forest processes as well as forest species." One evaluation question was stated in the 1994 ROD as: "Are habitat conditions for late-successional forest associated species maintained where adequate, and restored where inadequate?" The 1994 ROD stated that indicators for "assessing the condition and trends" include "seral development and shifts of forest plant communities," and that "key monitoring items" included "abundance and diversity of species associated with late-successional forest communities" and "species presence (to calculate species richness, that is, numbers and diversity" (E-8–E-9).

The 1994 ROD also called for validation monitoring, which it defined as determining "if a cause and effect relationship exists between management activities and the indicators or resource being managed." The 1994 ROD stated that validation monitoring asks "are the underlying management assumptions correct? Do the maintained or restored habitat conditions support stable and well-distributed populations of late-successional associated species?" The 1994 ROD also noted that key items to monitor include "rare and declining species" of plants or animals, including those federally or state listed, proposed, or candidate threatened or endangered, or listed by FS or BLM as sensitive or special status, or "infrequently encountered species not considered by any agency or group as endangered or threatened and classified in the FEMAT Report as rare." This validation monitoring would focus on "the type, number, size and condition of special habitats over time" to "provide a good indication of the potential health of the special habitat-dependent species" (p. E-10–E-11).

The 1994 ROD acknowledged that habitat requirements of species can vary with age, size, or life cycle of the species, and with season, and also that although stable habitats are "not proof that a special habitat-dependent species population is stable, a decrease in a special habitat type does indicate increased risk to that species population." The 1994 ROD also stated that "a monitoring program for rare and declining species will help to identify perceived present and future threats, increase future possibilities of discovering new locations, track their status and trends over time, and ensure that, in times of limited agency resources, priority attention will be given to species most at risk" (p. E-11).

The 2001 ROD (USDA and USDI 2001) stated that monitoring, including biological diversity effectiveness monitoring, should continue as specified in the original 1994 ROD. The 2001 ROD also specified that the strategic surveys and the ASRs would contribute toward the validation monitoring phase.

What Has Occurred and Were There Differences Between Expectations and Observations?

Species Outcomes

Focus on LSOG species—
The Plan was implemented as a set of guidelines for land management allocations, along with additional mitigation guidelines for the evaluation and disposition of LSOG species under the SM program. Implementation of the Plan for LSOG species focused on species and their habitat relationships, and not on other biodiversity parameters such as other levels of biological organization, ecosystem processes, and organisms' ecological functions. There has been no evaluation (including monitoring) of the degree to which the Plan has provided for these other aspects of biodiversity.

Evaluation of species rarity and persistence—
Under the ASRs, new data were collected on selected SM species and the species were reevaluated in an adaptive management framework to confirm or alter their conservation categories under the Plan. Although the term "rare" was never specifically defined by FEMAT or in the Plan, general criteria for determining species rarity were presented in the 2000 FSEIS and 2001 ROD (USDA and USDI 2000, 2001) that revised the SM program with new conservation categories. These criteria included consideration for total number of locations, habitat and population trends, habitat fragmentation and population isolation, ecological amplitude of the species, distribution limitations, dispersal capability, and other factors (table 8-1). None of the criteria, however, was quantified. Also, different and potentially conflicting sets of criteria were presented in the 2000 FSEIS and 2001 ROD for "rare" versus "uncommon" status of the SM species. Also, no specific criteria or procedures were presented for determining overall viability of the SM species (see later discussion on viability issues).

Results of forest vegetation monitoring (Spies, chapter 6 this volume) suggest a net increase in the total area of what is classified as late-successional and old-growth forest vegetation cover over the decade of 1994-2004. However, it is not known the degree to which this "in-growth" of the old-forest vegetation age class provides specific sites or microhabitat conditions used and selected by the individual species addressed in this chapter, nor if forests lost to fire and other causes over this same period eliminated any such sites and microhabitats.

Surveys of rare species conducted—
The original assumption that many of the LSOG-associated species are rare has been partially borne out by surveys conducted over the past decade under the Plan. Data collected over the last decade on number of locations of 399 SM species suggest that many of the species are known only from very few sites. About 42 percent of all species have been found from 10 or fewer sites (accounting for 6 percent of total sites in the database) (table 8-2). On the other end of the abundance spectrum, about 5 percent of the species account for most (two/thirds) of the sites and likely are not rare; these patterns held among all taxonomic groups (figs. 8-2 and 8-3).

The four arthropod functional groups were included in the Plan because of concern that catastrophic disturbance, particularly wildfire, in southern Oregon and northern California could jeopardize their persistence. Given the impractical nature of surveying for potentially tens of thousands of arthropods in the four functional groups (at least some of which are likely to be unnamed species), the arthropod team instead chose a research strategy with three components: (1) examine the effects of experimental thinning and burning on select functional groups in a long-term

Table 8-1—Surrogate measures of population persistence and disposition under the Plan, as specified in the guidelines for the annual species review of nonfish LSOG-associated species other than northern spotted owls and marbled murrelets

Parameter	Surrogates
Geographic range	Occurrence of species within or close to the Plan area Occurrence of suitable habitat within the Plan area
LSOG association	Abundance in LSOG Association with LSOG components Known association with LSOG forests Suspected by experts to be LSOG associated BLM or Forest Service special status species Listed by states as species of concern Federally listed by U.S. Fish and Wildlife Service as threatened or endangered U.S. Fish and Wildlife Service candidate species Adequacy of field data to determine LSOG association
Population persistence provided by the Plan	Likely extant known sites occurring in part or all of its range Total number of individuals Number of individuals at most sites or in most population centers[a] Estimated total number of sites[a b] Limitation of geographic range to the Plan area Distribution of habitat within the Plan area Distribution of individuals within the overall range of the species Proportion of sites and known habitats in reserves Proportion or amount of potential habitat within reserves Probability that habitat in reserves is occupied Whether all other guidelines of the Plan provide for population persistence
Data sufficiency	Sufficiency of information for evaluating basic criteria for including on SM species list Sufficiency of information for determining management for a reasonable assurance of persistence
Practicality of surveys	Predictability of the occurrence of the organism Visibility of the organism Limitation of expertise for identifying the organism Ease of identification of the organism Concerns for safety of surveyors Risk to the species from collection for surveys Surveyable in two field seasons Survey methods can be developed within 1 year

Table 8-1—Surrogate measures of population persistence and disposition under the Plan, as specified in the guidelines for the annual species review of nonfish LSOG-associated species other than northern spotted owls and marbled murrelets (continued)

Parameter	Surrogates
Species rarity	To determine if the species is “rare:”
	Limited distribution
	Distribution within its range
	Distribution within its habitat
	Dispersal capability on federal land
	Reproductive characteristics that could limit population growth rate
	Number of likely extant sites on federal lands
	Number of individuals per site[a]
	Population trend declining or not
	Number of sites in reserves
	Likelihood of sites or habitats in reserves
	Ecological amplitude
	Habitat trend declining or not
	Habitat fragmentation lending to genetic isolation
	Availability of microsite habitats
	Factors beyond the Plan affecting rarity
	To determine if the species is “uncommon:”
	Number of extant sites
	Number of individuals per site
	Restriction of distribution within range or habitat
	Ecological amplitude
	Likelihood of sites in reserves
	Population or habitat stability

Note: LSOG = late-successional and old-growth forests.

[a] Information derived from the random grid surveys (see text for explanation).

[b] Not explicitly included as a guideline in the 2001 ROD but added as a criterion to the annual species review.

Source: USDA and USDI 2001.

Table 8-2—Number of Survey and Manage program species and their total locations within range categories of known locations

Number of known locations per species	Number of species	Percentage of total number of species	Total locations
0	22	6	0
1	26	7	26
2-5	72	18	237
6-10	48	12	401
11-20	48	12	711
21-50	60	15	2,059
51-100	36	9	2,793
101-300	51	13	8,306
301-500	9	2	3,383
501-1,000	9	2	5,989
>1,000	18	5	44,347
Total	399	100	68,252

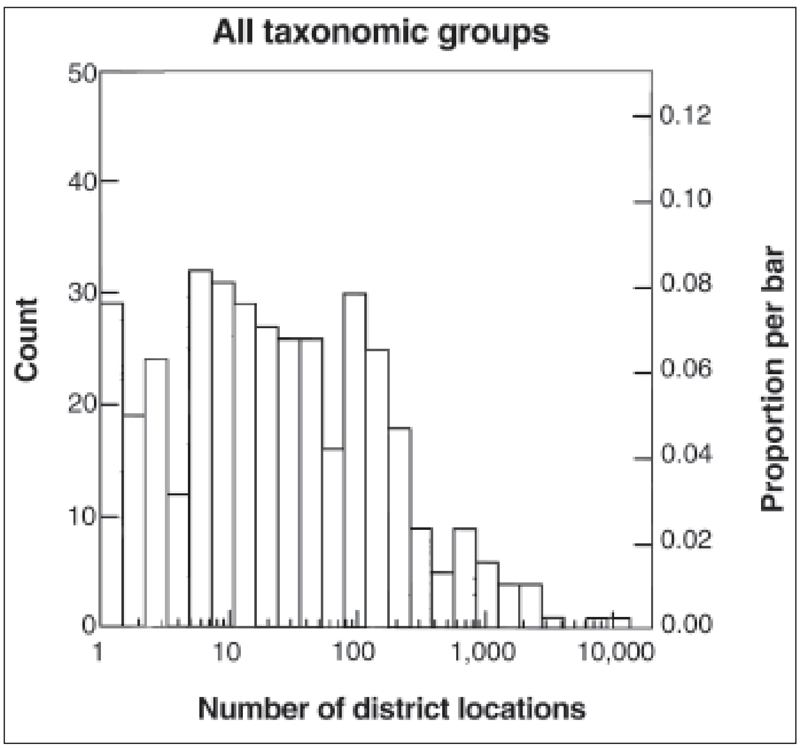


Figure 8-2—Species abundance distribution of number of distinct locations of Survey and Manage species (sites located through various surveys) within the Plan area, combined over all taxonomic groups. Note $\log_{10}$ scale on x-axis. Note that most species are rare, (known from very few sites), but some species are apparently more abundant.

Red Tree Vole

Red tree vole (*Arborimus longicaudus*) was a good example of a Survey and Manage (SM) species for which a great deal of work was done on developing survey protocols, conducting both strategic and predisturbance surveys for nests, and mapping nest locations to determine discrete population distributions for use in the annual species reviews.

One unique contribution to understanding and mapping distribution of this species came from Eric Forsman's research on northern spotted owls. The owl uses the vole as a primary prey item in a portion of the owl's range. Forsman was able to map the vole's distribution as a function of the appearance of the vole in owl pellets (Forsman and others 2004).

Other efforts on red tree voles included developing habitat prediction models and identifying high-priority sites. These tasks proved more involved and difficult than first envisioned because interpretation of the wide variety in the kinds of data available–including interpreting historical sites, potential nest sites, and active nest sites in terms of size and distribution of potential and active colonies—proved to be a challenge.

The red tree vole became one of the more problematic SM species because numerous nest sites were found through predisturbance surveys in the heart of its range in southwest Oregon on matrix land allocations. A large portion of timber harvest was planned for this area, and the presence of red tree vole nests interfered with that harvest, frustrating the management agencies. In the final 2003 annual species review, however, data from all of the combined survey, research, and modeling efforts provided the needed information for managers to decide to remove the red tree vole from the SM list, except for a small population in the northwest Oregon Coast Range. That population was later moved to the agencies' sensitive and special status species program in the 2004 record of decision.

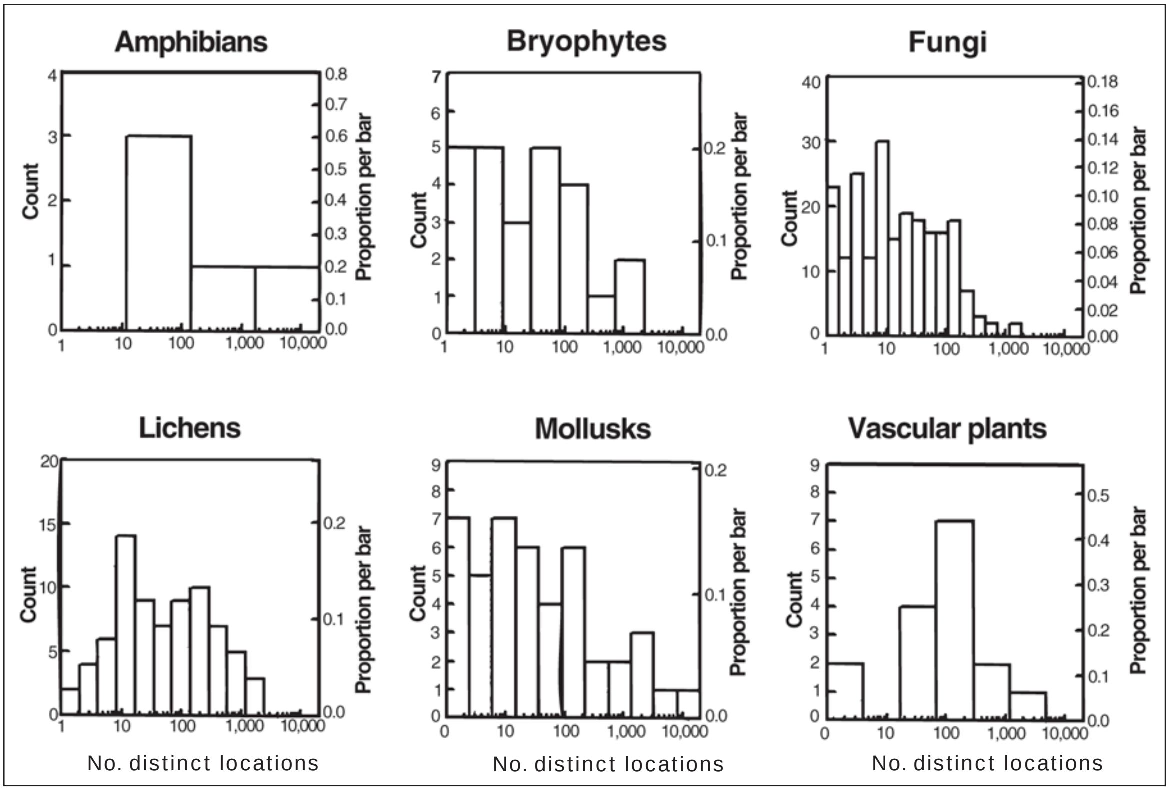


Figure 8-3—Species abundance distributions of number of distinct locations of Survey and Manage species (sites located through various surveys) within the Plan area, by taxonomic group. Note $\log_{10}$ scale on x-axis.

ecological research site in northern California and identify indicator species, (2) conduct retrospective studies of resilience and recovery of the functional groups in areas with different fire histories in southern Oregon, and (3) conduct extensive literature reviews of insects in the region to identify potential treats to persistence. These were multi-year studies funded at about $200,000 to $300,000 per year for 3 to 4 years, resulting in a set of publications and reports answering the basic three research components (for example, Niwa and Peck 2002).

Assumptions of persistence of some species—
The general assumption under the Plan that the 791 LSOG species not originally included in the SM mitigation are indeed viable and persistent (and thus not requiring SM mitigation) remains formally untested, although these species might have benefited from increases in LSOG and the reduced harvests over the past decade. No specific monitoring was established on these species under the Plan. Ancillary information may be available on some of these species under other research studies or agency programs (for example, the Demonstration of Ecosystem Management Options [DEMO] project, research studies of riparian-associated species, effects of retention, and effects of silviculture on suites of species), but this has not been compiled and analyzed.

Identification and protection of LSOG species habitats and locations—
The expectation that the Plan would protect suitable locations or environments for many of the LSOG-associated species is partially borne out by results of the surveys that suggest that many species locations occur within Plan reserves (fig.8-4). Many of the locations of fungi, lichens, bryophytes, and mollusks occurred outside

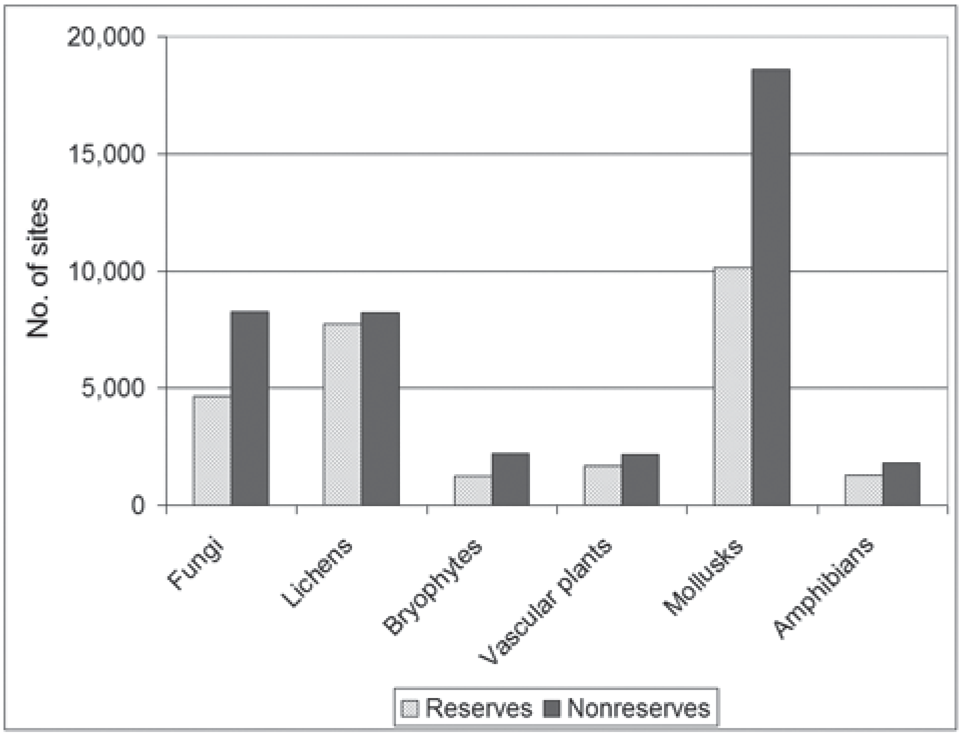


Figure 8-4—Number of known sites of species closely associated with late-successional and old-growth forests, located through various surveys, by reserve and nonreserve land allocations on Bureau of Land Management and Forest Service lands within the Plan area. Reserves include adaptive management areas, administratively or congressionally withdrawn areas, and late-successional reserves; nonreserve lands include riparian reserves (not separable in the database) and matrix lands.

Plan reserves. Survey and Manage species could occur within the Plan reserves, and within LSOG in those reserves, in part by chance. Some SM species likely occur in reserves and matrix sites in non-LSOG vegetation stands having some LSOG components, such as large standing or down wood legacies.

Regardless, the degree to which locations within the Plan reserves would suffice to provide for long-term viability of the other 791 LSOG species was not determined. Additionally, no monitoring per se was instituted for either the original set of 404 SM species and 4 arthropod species groups or for other aspects of LSOG biodiversity. Only various surveys have been conducted, mostly for predisturbance evaluation.

A total of 67,891 locations are known within the area of the Plan on all originally listed 404 SM species of all taxonomic groups, among all types of surveys (predisturbance, random grid, and other). Of this total, 26,676 locations (39 percent) are in reserves. Among taxonomic groups, the proportion of all locations from reserves ranges from 35 percent (10,125 of 28,730 locations) for mollusks to 49 percent (7,742 of 15,942 locations) for lichens. These results are likely biased toward locations outside reserves (viz., in matrix lands) where predisturbance surveys were conducted. Of the total surveys conducted, 79 percent are predisturbance surveys. Protecting SM species sites in matrix lands had a far greater perceived impact on PSQ than expected. This was primarily due to the 5 percent of the species noted previously that turned out not to be rare and were found with predisturbance surveys at nearly 40,000 sites, mostly in matrix lands (see lessons learned for further discussion on implications of the predisturbance survey approach).

Turley (2004) estimated that 67 percent of the federal land base of the Plan area consists of reserves, which include administratively and congressionally withdrawn areas, late-successional reserves, and managed LSRs. The remaining 33 percent consists of matrix lands, which here include timber management matrix lands, adaptive management areas, and riparian reserves designated under the Aquatic Conservation Strategy of the Plan. Not all LSOG forest occurs in reserves, and not all reserve lands are LSOG forest; USDA and USDI (1994a) estimated that 86 percent of existing late-successional forests are in reserves, so 14 percent are in matrix lands.[4]

Program Outcomes

Adaptive management approach and annual species reviews—
In general, the SM program did provide a useful adaptive learning framework by which new inventory and scientific information on the SM species was collected and analyzed, such as on number of locations from predisturbance surveys (figs. 8-5a, 8-5b) and other survey and information gathering efforts. The new information was used in the ASR procedures to reevaluate the conservation management status of each SM species, leading to the removal of some hundred species (about 25 percent) from the SM list during the overall SM program (fig. 8-6). This was a significant achievement, based on an unprecedented, massive database on species locations.

The ASRs also served to reassign some species to different conservation categories as a function of new scientific information mostly on their distribution and habitat associations. For example, the 2003 ASR evaluations resulted in removing from the SM program 29 (16 percent) of the 181 species evaluated that year, based on new scientific information. The 2003 ASR also reassigned 65 (36 percent) of the species to a more conservative category, kept 75 (41 percent) of the species in the same conservation category, and moved 41 (23 percent) of the species to a less conservative category, with no voting bias detected among the ASR panelists (Marcot 2003, Marcot and Turley 2003). These changes–again, part of the adaptive management approach–were scientifically supported by findings from the vast inventories conducted through the SM program.

Effective survey protocols and species surveys—
Many expectations for the SM program were met, particularly for developing and instituting effective species survey protocols, conducting predisturbance and strategic (including random-grid) surveys (Molina and others 2003), accreting new data on species locations, developing databases and GIS information bases (with about 68,000 records), synthesizing science information for individual species into management recommendations and applying those recommendations to project plans, and identifying sites for which protection outside LSRs would be provided. Multispecies, probabilistic regionwide surveys called for in the 2001 FSEIS were developed and implemented that provided opportunities to examine regional species distributions in reserves and their rarity.

Development of species evaluation tools—
Also, useful tools, such as decision models based on the 2001 ROD evaluation criteria, were developed and successfully used to aid decisionmaking during the ASR process (Marcot and others, n.d.). Other models (viz., potential natural vegetation GIS models, for example,

[4] The riparian reserves have not been fully mapped, so there is no individual estimate of their areal extent nor the percentage of LSOG forest therein. However, USDA and USDI (2004b: 11) noted that "matrix and adaptive management area" land allocations constitute 19 percent of the Plan area. Presuming that "matrix" lands here do not constitute riparian reserves, one could estimate that riparian reserves might constitute 33 - 19 = 14 percent of the Plan area. Added to the other reserve lands, this totals 67 + 14 = 81 percent of the Plan land area in reserves including riparian reserves. There is no mapped information, however, on the extent of LSOG forest in riparian reserves.

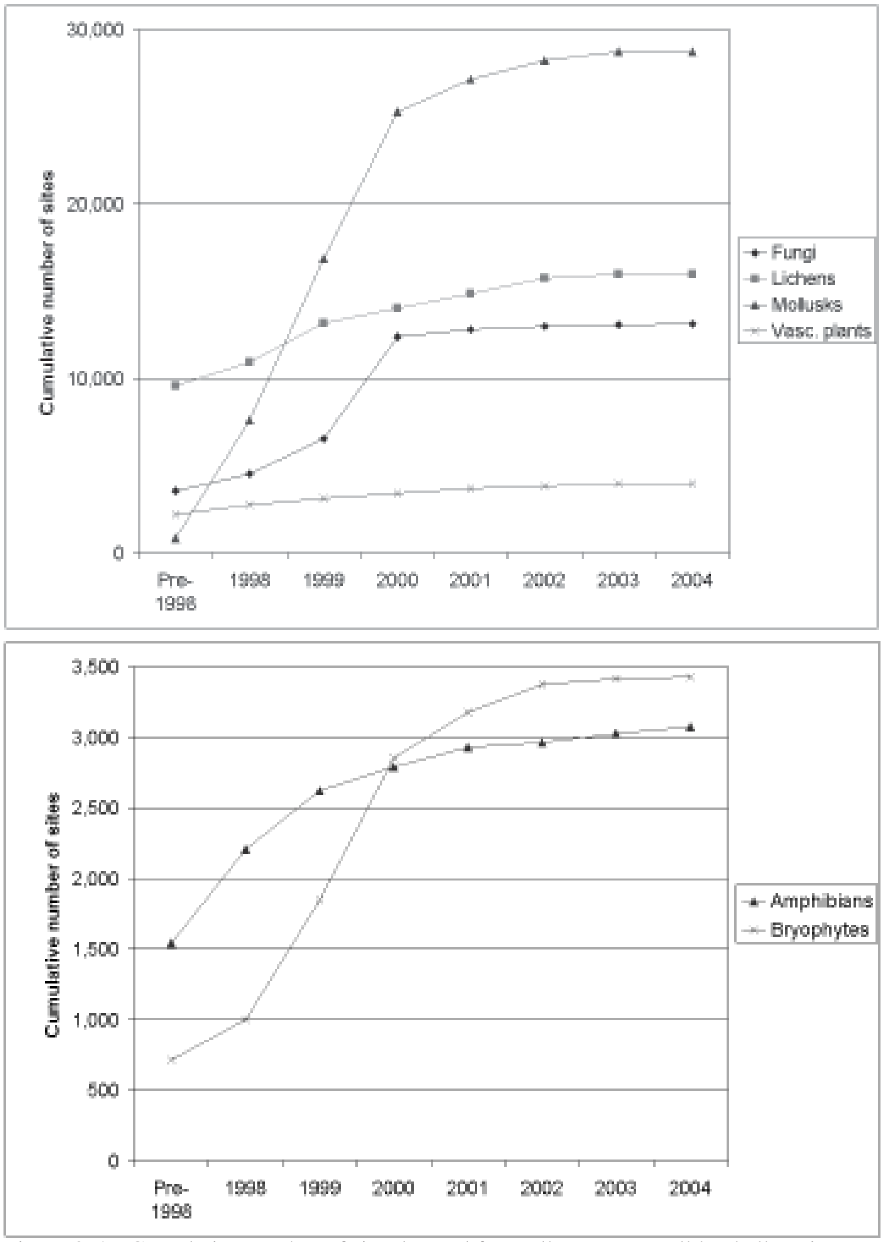
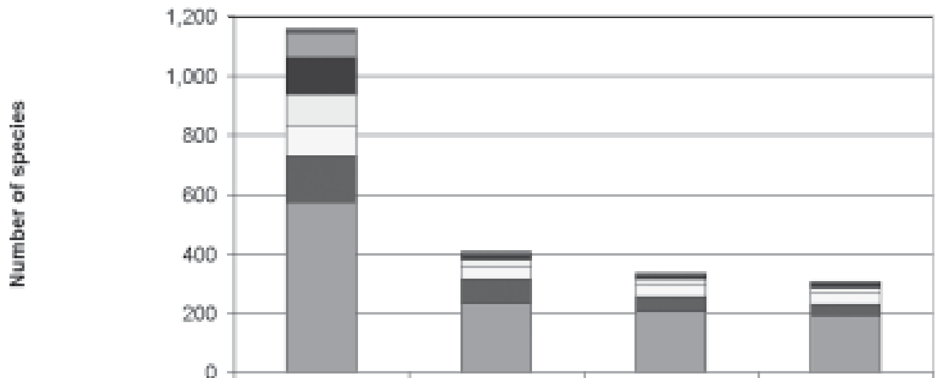


Figure 8-5—Cumulative number of sites located from all surveys on all land allocations (reserves and matrix lands), by taxonomic group and year. Substantial progress was made in locating sites particularly between 1998 and 2000.



	FEMAT analysis	Original guidelines	Revised guidelines	Current
Arthropod groups	15	4	4	4
Vertebrates	82	6	6	5
Vascular plants	124	17	12	12
Bryophytes	106	23	17	15
Mollusks	102	43	43	39
Lichens	157	81	48	43
Fungi	572	234	208	189

Figure 8-6—Number of species assumed closely associated with late-successional and old-growth forests as listed by the Forest Ecosystem Management Assessment Team (FEMAT) in 1994, in original guidelines of the 1994 Environmental Impact Statement (FSEIS) and Record of Decision (ROD) that instituted the Survey and Manage (SM) program under the Northwest Forest Plan, in the revised guidelines of the 2001 FSEIS and ROD that revised the SM program and its annual species review process, and "current" in 2004 at the termination of the SM program. The decline in number of species was because of new information used in the adaptive management process of the annual species reviews.

Lesher 2005; and Bayesian belief network models, Marcot, n.d.) for evaluating likelihood of habitat suitability for specific SM species had been developed but were only partially integrated into the program.

Some shortcomings in surveys—
Some expectations for the SM program were not met, however, including the following. The SM program, particularly the predisturbance surveys and ASR procedures, proved to be far more expensive and administratively complex than initially expected. Except for a few species, high-priority sites were not identified for protection, as called for in both the 1994 and 2001 RODs. Data on absence (lack of presence) of species from field surveys, particularly from predisturbance surveys, were not recorded, which was a major loss of otherwise useful information to build and test prediction models of species-habitat associations. Little habitat or species abundance data were collected in pre-disturbance surveys, similarly impeding the ability to construct habitat models or incorporate population attributes into conservation plans.

What Was the Extent to Which Differences Were Caused by the Northwest Forest Plan?

Species Outcomes

Conservation of LSOG species—
Many or most of the 1,120 LSOG-associated species originally identified by FEMAT are likely far better

conserved owing to the Plan, simply by dint of conservation of LSOG forests and forest elements in LSRs, riparian reserves, and matrix management guidelines providing for protection of known locations of some LSOG species. Much information has been collected on the number of sites that were protected for each species. Although that information does not translate to population outcomes, it is nevertheless a significant finding. However, the specific population outcomes, especially of the rarest of SM species, are largely still unknown.

Little information on species persistence—
Much of the implementation of the Plan for other species has focused on procedures for identifying and, where appropriate, protecting locations of rare and little-known, LSOG-associated species, and gathering new information on their associations with land allocations and habitat conditions. Little work has been done on species trend monitoring, and on validation monitoring of the expectations that the Plan has provided for their long-term persistence and viability.

Thus, it is difficult to conclude whether the Plan has indeed provided for the long-term persistence and viability of these species, although (1) protection was afforded to specific matrix land locations when identified through predisturbance surveys and (2) much of the managed landscape occurs as reserves in which a significant amount of LSOG forest remains and LSOG species locations occur. The assumption that the Plan has provided for viability—or conversely, that it has not adequately provided for some species—is still a hypothesis to be tested, at least by monitoring trends in species' locations over time, although we have some incremental, useful insights on locations and number of occurrences of some species from the various surveys.

Much uncertainty remains on whether the Plan has indeed provided for the long-term persistence and viability of a number of the LSOG-associated species and their ecosystem functions, particularly for the more rare of the SM species. A number of the less rare SM species, however, were removed from the SM species list by the annual species reviews, and these species were deemed to be secure under the Plan.

Some major reductions in uncertainty—
Although much remains to be learned about life histories and ecological functions of most LOSG species, knowledge gained on specific distribution and abundance of many of these species has helped greatly reduce scientific uncertainty. In turn, as used in the ASR process, this information helped reduce management uncertainty and increased reliability of management decisions on the conservation requirements of these species. This has not been a trivial accomplishment.

Still, some scientific and management uncertainty remains, including on SM species that were "downgraded" in conservation status under the SM species program, because only indirect, surrogate measures were used to judge the species' persistence. For some species, better data were gathered by use of random grid (strategic) surveys, species-habitat modeling, and other efforts. For these species, some of the uncertainty in their projected persistence was greatly reduced.

Program Outcomes

Perceived impact on timber PSQ—
The predisturbance surveys and their results impacted matrix land management and were viewed as being largely responsible for a far greater impact on PSQ than initially expected (see lessons learned for more details).

Organizational complexity—
Working across agencies to evaluate the entire federal land base (BLM + National Forest System) created a layer of organizational complexity that (adversely) affected timeliness in getting work done, and also in running a regional program that had a large component independently implemented by field staff. We discuss organizational issues further under lessons learned.

Avoiding federal species listings—

The expectation that the Plan would help stave off federal listing of LSOG-associated species has been largely borne out, although listing petitions have been advanced for a few species including lynx and fisher. It is unclear, however, whether the lack of listing petitions for other LSOG-associated species was directly a result of the Plan, although the Plan likely contributed to this outcome.

Are the Northwest Forest Plan Assumptions Still Valid?

Species Outcomes

Most LSOG species protected—

The initial projection that the main elements of the Plan would provide LSOG environments for most, but not necessarily all, species is still valid. Population persistence of the 404 SM species and 4 arthropod species groups–as well as the 791 species deemed to be effectively cared for under the Plan–is still untested.

Protection of some of the rarest species provided, others still uncertain—

The expectation that some species might garner additional conservation attention beyond the main elements of the Plan (Aquatic Conservation Strategy, riparian reserves, LSRs, matrix guidelines) was validated by the work of the annual species reviews. That is, based on the outcome of the ASRs, the late-successional and riparian reserves might **not** suffice to fully ensure protection and persistence of all LSOG species. Additional, species-specific assessments and considerations, as were conducted under the SM program and ASRs, likely are part of meeting this goal. This is particularly true for the rarest species (that is, those known from <20 sites) that had known locations outside of reserves. Thomas and others (1993) provided a detailed example of increased levels of protection granted to species with the addition of each new layer of a multilayered plan such as the Plan. One of the successes of the SM program was identification of known sites for protection of the rarest species outside reserves.

Program Outcomes

Disposition of the SM program—

Final consideration of the validity of Plan assumptions for the SM program is problematic because the SM standards and guidelines were removed from the Plan in 2004 (USDA and USDI 2004b). The SM program was controversial since its inception, resulting in litigations with different publics and eventual development of two SM FSEIS analyses and RODs to deal with implementation issues. Some of those issues were noted above, particularly the adverse impact on PSQ of management decisions not to continue projects (for example, timber harvest) in numerous matrix sites where SM species were detected through predisturbance surveys. The 2001 ROD (USDA and USDI 2001) also documented the adverse impact of SM mitigation activities on ability to conduct healthy forest and fire reduction projects in much of the Plan area.

In response to a 2001 lawsuit brought by the timber industry (Douglas Timber Operation, and others v. Secretary of Agriculture. Civil No. 01-6378 – AA), the administration settled and agreed to conduct a new EIS on the SM program wherein one alternative would consider movement of SM species to the agencies' special status and sensitive species programs (SSSSP). In the resulting 2004 SM FSEIS (USDA and UDSI 2004a), the agencies described their many frustrations in implementing the SM program mitigation and overall adverse impact it had on meeting other important Plan objectives (for example, PSQ, healthy forest restoration, and other management projects) and the high cost of the program. They selected a preferred alternative that removed the SM standards and guidelines developed in the 1994 and 2001 RODs (USDA and USDI 1994b, 2001) and moved 152 of the remaining 296 species into the BLM and FS SSSSP; 57 species not added to the SSSSP were projected to have insufficient habitat for persistence under this preferred alternative compared to a projection of sufficient habitat under the 2001 SM ROD (USDA and USDI 2001). The 2004 FSEIS and ROD clearly described the risks to species extirpation and management risk tolerance in making these decisions. The agencies emphasized the probable contributions of the Plan area in LSRs (80 percent of the Plan area), the risks to rare species persistence inherent in dynamic landscapes, and the stated desire to balance the uncertain nature of conserving these rare and little-known species with meeting other critical Plan objectives (see USDA and USDI 2004b: 9-13, for more details). Costs and benefits of the SM program were also given detailed analyses.

The 2003 FSEIS and 2004 ROD provided detailed effects analyses on the risk of extirpation of SM species under the three alternatives based on available data and expert opinion. The overall objectives of the SSSSP differ from the SM program, and SSSSP coordinators and field managers face many of the same challenges that SM staff did in conserving these species; many of the SM taxa such as fungi have not previously been included in the SSSSP. Therefore, the SSSSP could take advantage of the known site database, distribution maps, science documents, management guidelines, survey protocols, and conservation strategies pioneered and developed by the SM program. In approving the 2004 ROD, the regional executives apparently clearly understood the challenges and impact of moving 152 SM species to the SSSSP in Oregon and Washington, and have supported this transfer of knowledge gained from SM. They also have increased resources (funding and permanent regional staff) to accomplish the increased workload for these and other tasks. A section that follows on information gained and lessons learned from the SM program further supports the potential value of transferring key findings. The 2004 ROD was challenged by environmental groups, and in January 2006, the court ruled that the SM program be reinstated according to the 2001 ROD. It remains uncertain how the agencies will restart and continue the SM program and how a new FSEIS now underway will modify the program.

Information Gained and Lessons Learned

Information Gained on Rare and Little-Known Species

One of the underlying challenges, and indeed an underpinning for the adaptive approach of SM, was lack of fundamental information on species presence, distribution, abundance, biology, ecology, and conservation status: How rare are they? How are they distributed throughout the Plan area? How abundant are their populations? What are their primary habitat requirements? What factors are influencing their risk of extirpation? Answers to these questions are fundamental to discovering how well the Plan provides habitat for maintaining well-distributed, viable populations (that is, meeting the original mission objective for LSOG-associated species) and how to best manage, protect, or restore habitat to meet that original objective. The collection of nearly 68,000 known site records for all SM species over 10 years of Plan implementation provided the basis for unraveling some of this uncertainty for many species and allowed for informed science-based management decisions on their conservation.

Given new information on rarity, distribution in reserves, degree of LSOG-association, and persistence concerns, over 100 species were removed from the SM list because they no longer qualified for the SM mitigation. Many of these species were removed because they were not as rare as originally believed. The removal of these less rare species was an important adaptive decision because they accounted for many thousands of sites in the matrix; once removed from SM, these sites were released to meet other forest harvest and management objectives.

Known site data also showed that most SM species were rare; 54 percent of the species were known from 20 or fewer sites, 42 percent from 10 or fewer sites, and 31 percent from 5 or fewer sites. The SM database includes sites from both federal and nonfederal forests. When nonfederal sites are removed from consideration, the percentage of actual sites protected under the Plan was smaller. Given the high percentage of species that showed such rarity, these data support the assumption made during

Del Norte Salamander

At the initial implementation of the Plan, the del norte salamander (*Plethodon elongatus*) was thought to be a rare species endemic to southwest Oregon and northwest California. Predisturbance surveys were required for the del norte salamander starting in 1996, and by 1999 approximately 882 sites were located, 36 percent occurring on matrix land allocations (Nauman and Olson 1999). The number of sites increased to 1,000-1,500 over the next few years. Considerable reserve land also occurred within the range of the del norte salamander, but the reserve land had received little survey effort. It remained unknown how well the reserves were contributing to the persistence of the species. In 2000, a strategic survey was conducted in the region to examine del norte salamander distribution in reserves. Approximately one-third of all surveys conducted in the reserves yielded presence of the salamander. This new information on potential distribution in reserves, together with the high number of known sites (that is, less concern about rarity) provided support for removing the salamander from the SM list during the 2001 annual species review. This adaptive decision released many hundreds of sites in matrix lands for subsequent timber harvest and other management activities. This exemplified the ability of targeted, strategic surveys to supplement the typically biased records from predisturbance surveys and provide the underpinning for making better science-based decisions on species persistence and management needs.

FEMAT and the 1994 FSEIS (USDA and USDI 1994a) that application of a fine-filter strategy, in this case protection of known sites, would be an important strategy to maintain their viability. The discovery of many of these rare sightings outside of reserve land allocations further supported the protection of the few known sites to meet the objective of helping ensure conservation of these species.

Although the nearly 68,000 records allowed for better informed decisions, the data had shortfalls that limited their utility for answering the many questions noted previously. Lessons learned emerge from understanding the usefulness or limitations of the data. The vast majority of records are simply site locations with little or no information on habitat characteristics or species abundance. Thus, even though distribution maps could be generated, they could not be used directly to analyze population trends and dynamics, nor to predict potential habitat or its distribution. Collecting information on species abundance or habitat characters represents a significant expense compared to noting only presence.

It is important to carefully weigh what information helps to meet conservation objectives and the cost and benefit of obtaining that information in future inventory or monitoring surveys. If surrogate metrics are used to gauge species persistence and to reduce survey cost (for example, using rarity alone without species abundance data), the science panel evaluations of the SM program's annual species reviews taught the importance of knowing the limitations of the data and integrating its uncertainty into management decisions (see later discussion on use of surrogates in species viability analyses).

There was also significant bias in the nearly 68,000 records because most were from predisturbance surveys conducted primarily in matrix land allocations. This bias would be considered when addressing questions of how well the Plan, particularly the reserves, provided habitat for well-distributed, viable populations. The course change documented in the 2001 SM ROD toward more reliance on strategic (including random-site) surveys than on pre-disturbance surveys was directed at resolving this issue.

Regardless of these shortcomings, on a regional scale, the nearly 68,000-record database is one of the largest and richest of its kind for poorly known taxa such as fungi, lichens, bryophytes, and mollusks. It could serve not only as a valuable resource for the SSSSP of Oregon and Washington, but the rigorous procedures for inventory and amassing survey data could help in developing conservation strategies for rare and little-known taxa in other regions.

Information Gained and Lessons Learned From the SM Program

The SM program ploughed new ground in the science and conservation management of rare and little-known species. Results of the SM program are pertinent not only to the stated objectives of the SSSSP, but also to conservation programs worldwide that are grappling with similar challenges in conservation of rare and little-known species. In identifying the challenges of managing biological diversity in Oregon and Washington as part of the PNW Station's Biodiversity Initiative (Molina 2004), Nelson and others (2006) found that numerous clients from inside and outside federal agencies voiced the desire to summarize and make available results from the SM program. We highlight here some of the major results and accomplishments of the SM program with a focus on lessons learned for potential use in future conservation efforts.

Management recommendations, survey protocols, and field guides—

Developing science-based management recommendations was critical to meeting the assumption that agencies could provide immediate site management for species of high concern. The management recommendations documents served two major functions. First, they summarized the best knowledge available on the biology, ecology, and natural history of the species. Second, they synthesized and integrated this knowledge into flexible guidelines so that managers could manage sites within their overall planning objectives. Recommendations focused on guidelines to maintain suitable habitat for species at the site scale.

Survey protocols identified when and where surveys were to be done, and the sampling procedures, the information to collect, and the survey skills required. Field guides for collection, identification, and processing of fungi and mollusks, two of the more difficult taxa, also were developed (for example, Castellano and others 1999, 2003; Frest and Johannes 1999). All management recommendations, survey protocols, and field guide documents are available on line (www.or.blm.gov/surveyandmanage) and provide the most extensive management guidance to inventory and manage habitat for these taxa. These documents are available for the SSSSP efforts.

Development of an interagency species database—

As directed under the 1994 ROD, the SM program strove to develop an interagency database capable of mapping known locations through GIS procedures to aid analysis of other critical habitat and species attributes.

Development began as a simple "known site" database with much of the information coming from herbaria, museums, and agency data collected as part of the FEMAT and the Plan processes. In 1999, the new database (called the Interagency Species Management System or ISMS) came on line with full-time staff. After extensive training of field staff on ISMS use, new data were entered and analyses conducted as part of the annual species review process. At the conclusion of the SM program nearly 70,000 survey records were housed in the ISMS database. This is the largest known assemblage of site and habitat data for these particular taxa.

The data, resulting maps, and analyses were used in the ASR process and, later, by the Natural Heritage Program to place species into the agencies' SSSSP when the SM program was terminated. The ISMS database has now migrated to the new interagency Geographic Biotic Observations (GeoBOB) database and provides the framework for future GIS analysis and planning for the conservation of species in the SSSSP program and elsewhere.

Predisturbance surveys—

The intent of predisturbance surveys was to avoid the inadvertent loss of sites to maintain species persistence, particularly for rare species found outside reserves in matrix lands. As noted previously, predisturbance surveys became the most costly and controversial part of the SM program.

The 1994 ROD stated that most preproject surveys would begin with a watershed analysis and would identify likely habitat therein that required survey of the SM species. However, because so little was known about the habitat for these species, most surveys were conducted at the project level (that is, nearly all management projects required preproject surveys, often for multiple species). Surveys often were expensive and constrained by lack of trained personnel, and some species survey protocols were difficult and time consuming.

Field managers often stalled or cancelled projects because of the presence of SM species at the project sites. Eventually many of these species that turned out not to be as rare as previously known were removed from the SM program, but not until late in the program. The end result was a major impact on meeting the timber PSQ.

Although the conduct of predisturbance surveys met the expectation of avoiding inadvertent loss of sites, it became an unintended dominant aspect of the program. About 75 percent of all ISMS records were from preproject surveys, and these were only for about 10 percent of all SM species. When survey protocols were developed, data on habitat features and species abundance were not required, so these survey records mostly consisted of only a "known site" location. Nor were negative findings typically recorded from these surveys. The predisturbance survey data did not aid understanding of species' habitat requirements and had limited utility for building habitat models of species' habitat associations by which to predict occurrence on the landscape.

Three valuable lessons emerge from the predisturbance survey effort: (1) Predisturbance surveys can locate new sites and aid in rare species protection, but often provide biased data of limited value in understanding species distribution, habitat selection, persistence, and conservation management. (2) Presence/absence data is of limited value in understanding species viability and conservation management; data on habitat and species abundance are required to better inform decisions on management for species persistence. (3) An adaptive process to quickly review and evaluate the effectiveness and cost/benefit of survey strategies is important to meet long-term goals. The 2001 ROD recognized some of these issues and emphasized that strategic surveys that would focus on reserve lands were required.

Strategic surveys—

Strategic surveys, which were to be conducted on both matrix and reserve lands as well as in LSOG and non-LSOG, were developed as an underpinning for the 2001 SM ROD for three reasons. First, the agencies recognized that predisturbance surveys were not targeting reserve lands because most projects occurred in the matrix. A fundamental uncertainty of the SM mitigation was how well the reserves provide for species persistence. Second, little habitat or abundance data were collected in preproject surveys; this information is vital to understanding habitat association and designating high-priority sites as part of conservation plan development. Third, the SM program was based on an organizing principle and vision tool to work through the priorities of the SM program to bring better balance to meeting species conservation with other Plan objectives such as timber harvest. The strategic survey effort together with the newly defined annual species review process was designed to address these issues.

The strategic survey effort followed the adaptive framework developed by Molina and others (2003). The framework represents an iterative process that identifies specific information gaps, prioritizes species based on biological or management gaps, designs and implements efficient survey approaches, and then analyzes the survey findings as part of the annual species review. A new set of information gaps is identified from these analyses and the planning and implementation process is repeated. The strength of this approach is that it is designed to address specific questions that reflect priority information gaps.

Strategic surveys included a wide variety of approaches to fill information gaps, including research and modeling approaches. This variety of approaches increases flexibility of the overall program and enhances opportunities for partnerships between managers and researchers. Such a flexible "strategic" approach could enhance the effectiveness of the SSSSP, particularly in dealing with species such as fungi where predisturbance surveys largely remain impractical. Landscape-scale surveys, for example, that cross BLM and FS district boundaries and that use a statistically designed sampling scheme, could help field managers to share resources for collecting and analyzing data throughout a significant portion of a species' range. We provide results below from one example of this approach, the random grid survey.

Random grid surveys—
In 1999, regional leadership requested development of a broad-scale survey throughout the Plan area that would provide valuable information on all SM species (that is, use a multiple-species approach) concerning their rarity and distribution in LSOG habitat and reserves. The survey would be statistically designed to allow for use of probabilistic inferences of species' occurrence across the Plan area. Working in consultation with a team of statisticians, a strategic survey workgroup developed what is called the random grid survey (see Cutler and others 2002 and Molina and others 2003 for a discussion of the strengths and weaknesses of this survey approach).

The random grid survey uses permanent points on the landscape (the forest inventory and analysis [FIA] and current vegetation survey [CVS] grid) that contain a wealth of information on stand age, composition, and structure (for example, amount of coarse woody debris and number of snags). Seven hundred fifty randomly selected sampling points were stratified into LSOG vs. non-LSOG (LSOG = forests >80 years) and reserve vs. matrix lands to address the primary questions of LSOG and reserve association of each species. Occurrence estimates of each species were calculated by extrapolation of the number of sites at which the species was found to predict occurrences over the survey area. Implementing this survey for about 300 species was extremely complex and expensive (about $8 million) and took over 2 years to complete. Nearly 240 people were involved in planning, execution, specimen identification, analysis, and reporting. Final results are still in the reporting stage so we can only provide a limited summary at this time.

Overall, it appears that the random grid survey met some of the original expectations and objectives. Approximately 3,000 new records were added on 179 SM species, roughly one third on lichens and another third on fungi. Figure 8-7 shows, however, that most species were found from only 10 or fewer sites each, one third were found from 1 or 2 sites, and 40 percent of the species were not found at all. This is the general result predicted by Cutler and others (2002) who noted that this broad-scale type of survey would likely not detect extremely rare species. Although that was true overall, a few very rare species (that is, known from only a few sites) were detected in the survey.

Results from the random grid survey also helped expand the known overall distribution of several species. However, evaluating the degree of association of the SM species with LSOG or reserve lands proved difficult because these analyses require at least 10 detections for a reasonable amount of certainty. Of the 41 species with 10 or more detections, about 30 showed a statistical association with LSOG and 7 with reserve or matrix land allocations (two with reserves and five with matrix). Regardless of statistically significant results, knowing that species were detected in reserves may be useful because this information was previously lacking in the ISMS database.

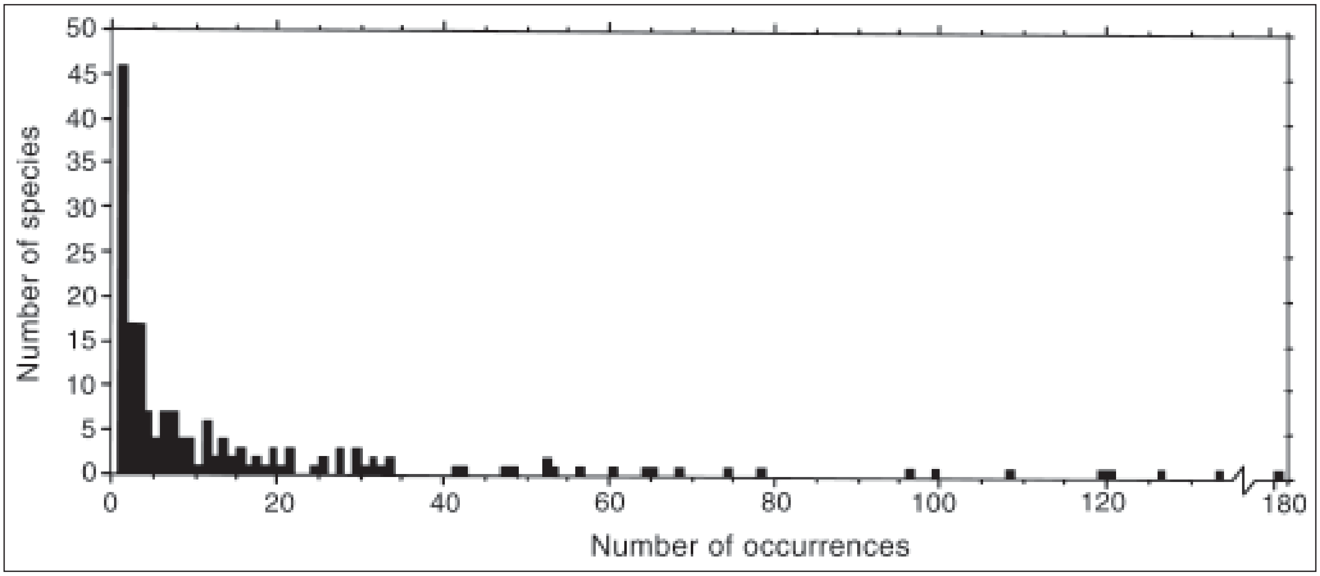


Figure 8-7—Distribution of number of species found at sampled random grid survey points. Data represent a total of 2,985 occurrences found among 179 species of bryophytes, fungi, lichens, and mollusks sampled on 660 grid points throughout the Plan area.

Figure 8-7 also shows that several species were detected frequently on the random grid. Most of these species had already been removed from the SM list or were being viewed in the annual species reviews as not rare.

Although the random grid survey data analyses were not completed prior to the termination of the SM program, preliminary results were used in the annual species review. For example, some species were removed from the SM species list in part because the random grid surveys suggested the species were not rare within the Plan area.

Given the mixed results (few to no locations of very rare species, but useful information on other species on LSOG and reserve association) and great expense of the random grid survey, the SSSSP may wish to carefully review the findings and identify advantages of this survey approach, to help meet program objectives (see Edwards and others 2004 for further discussion).

Annual species reviews—
One of the more successful outcomes of the SM program was the annual species review (ASR), designed as an adaptive decision framework to address uncertainty and provide new information to guide SM species conservation decisions (fig. 8-8). The 2001 ROD revised and expanded the ASR process and provided specific criteria and guidelines by which panels of species experts and evaluators would summarize and interpret ecological attributes of each SM species for reevaluation of the species' conservation status under the Plan.

Bruce G. Marcot

Figure 8-8—Annual species review panel of the Survey and Manage program being led by Russ Holmes. The panels were used in a successful adaptive management process to evaluate species conservation status under the Plan.

Using this process, the agencies removed about one quarter of all SM species from the list, and changed categories of several species to either a more or less conservatory status to reflect mitigation. Decisions to remove some species provided the agencies with the latitude to permit other management activities to proceed on those sites.

The ASR process was not a formal population viability analysis but rather a decision process that used a number of surrogate factors that represented species rarity and persistence. It is unlikely that traditional population viability analyses—which demand data on demography, population genetics, community interactions, and other ecological factors—could be conducted on most of the SM species owing to the species' rarity and to the dearth of quantitative information. Thus, it was vital to ensure that the ASRs served as a rigorous decision analysis procedure. To this end, the 2001 ROD guidelines specifying the criteria for the ASR species evaluations were formalized into a set of decision models (Marcot and others, n.d.). The models were used by the ASR evaluation panels to determine which categories of conservation status, if any, might pertain to each species given the scientific data. The models clearly showed how the surrogate factors were used to judge potential conservation status categories, and the ASR evaluation panel fully documented their use of the data and model outcomes in their recommendations. Thus, the overall ASR process was trackable, rigorously conducted, and fully documented. Many of the processes used in the ASR may prove valuable in assessing SSSSP species status and trends.

Selecting high-priority sites for management—
The 2001 ROD also specified identifying high-priority sites for some of the SM species categories (for uncommon species whose status was not determined). Selecting high-priority sites for management was intended to provide a measure of protection for the species but also allow some sites to be used for other management objectives such as forest stand thinning and timber harvest.

This aspect of the SM program was slow to be implemented, and by the end of the SM program, plans were still in developmental stages for only a few species. This was an unfortunate outcome because developing these plans (that is, selecting high-priority sites for management) was a key process to release known sites in the matrix for other management objectives.

The plans under development used information from watershed analyses to determine where critical sites occurred in relation to nearby reserves with suitable habitat. These plans and the process used to develop them may provide useful tools for the SSSSP, particularly in evaluating the degree to which reserve lands could provide for species and could thereby defer the development of site-specific protection measures.

Program organization and implementation—
Implementing the SM mitigation became a far more complex, expensive, and process-driven program than originally envisioned by the FEMAT and EIS writers (Holthausen 2004). Reasons for this are many and varied. Although some aspects of the SM program were expected to be expensive (tables 8-3 through 8-6), final costs exceeded expectations, particularly in conducting pre-project surveys throughout the region by field units (see USDA and USDI 2001 and 2004a for details on program costs). Available information makes it difficult to compare projected and actual costs.

The 1994 ROD provided little guidance for SM program organization and implementation. None of the original FEMAT or EIS team members who developed the standards and guidelines of the Plan program participated in early development or design of the SM program, so original intentions may have been lost or overlooked. A group of interagency specialists eventually formed a core team to develop the SM program of work. Most of these specialists were assigned only part time to this project, with some members coming and going as details ended. A shortage of taxa expertise within the management agencies surfaced early in SM program implementation and affected the

Noble Polypore


Forest Mycology Team

The noble polypore (*Bridgeoporus nobilissimus*) was unique among the original 234 SM fungal species. It forms large conks or shelf-like fruiting bodies up to a meter across at the base of large trees (it is a heart-rot fungus) that are perennial. Because the fruiting bodies of the noble polypore are always present and easy to detect, the species was listed under the original category 2 conservation status—survey prior to ground-disturbing activities. No other fungal species were placed in this category because of the difficulty in locating them through surveys in any given year.

The noble polypore was only known from six sites at the time of FEMAT, and two of those sites had no protection because they existed outside of reserve land allocations. Those two known sites were given unique protection in the original SM standards and guidelines: "Management areas of all useable habitat up to 600 acres are to be established around those two sites for the protection of those populations until the sites can be thoroughly surveyed and site-specific measures taken" (USDA and USDI 1994b: C-5).

Over the next several years those original sites were surveyed by the survey and manage mycology team and several new records of fruiting conks were noted. More importantly, detailed habitat data were collected at these known sites. A better understanding of required habitat emerged, which allowed for construction of habitat models (Marcot, n.d.) and targeted, purposive surveys into potential habitat in the region. A critical finding, for example, was the specific association of noble polypore conks with large stumps of *Abies procera* Rehd. in the Oregon Coast Range and *Abies amabilis* Dougl. ex Forbes in the Cascade Ranges of Oregon and Washington as well as the Olympic Peninsula. Subsequent surveys by expert mycologists found several new sites, approximately tripling the number of known sites and extending the known range. The species was not located in predisturbance or random grid surveys.

This provides a good example of using expert knowledge to build habitat models to better target regional surveys. The noble polypore was transferred to the agencies' Sensitive and Special Status Species programs in the 2004 record of decision.

Table 8-3—Projected (anticipated) costs for survey activities over the life of the Survey and Manage program[a]

Survey activity	Projected costs
	Thousand dollars
Bryophyte extensive and general regional surveys	100
Lichen extensive and general regional surveys	500
Vascular plants preproject surveys	330
Known locations for rare, endemic fungi (over 3 years)	1,000
Fungi extensive and general regional surveys (over 10 years)	10,000
Arthropods, 20 watershed surveys	9,000
Total	20,930

[a] Extensive and general regional surveys were expected to take at least 10 years.

Source: USDA and USDI 1994a, Appendix J2. Values do not include regional program implementation costs or predisturbance survey costs.

Table 8-4—Approximate regional expenditures of implementing the Survey and Manage program from 1994 to 1999

Cost element	Cost
	Thousand dollars
Program management	600
Preparation of survey protocols, management recommendations, and field guides	1,905
Training and species identifications	1,566
Extensive and general regional surveys[a]	2,875
Known-site database	610
Interagency Species Management System	1,100
Overhead	1,904
Subtotal regional program costs	10,560
Predisturbance surveys 1994-1998	1,000
Predisturbance surveys 1999	8,500
Total	20,060

[a] Did not begin until 1996.

Source: USDA and USDI 2000: 410-412.

Table 8-5—Annual projected (anticipated) short-term (1 to 5 years) and long-term (6 to 10 years) cost, projected from 2001 onward, to implement the preferred alternative for the Survey and Manage program

Program level	Cost element	Short-term cost	Long-term cost
		Thousand dollars	
Regional	Strategic surveys[a]	7,700	1,000
	Field guides, management recommendations, survey protocols	600	300
	Program management	500	500
	Data management	400	400
	Training, species identification	600	600
	Subtotal	9,800	2,800
Field	Predisturbance surveys for timber	8,200	6,100
	Predisturbance surveys for fire	10,300	7,700
	Predisturbance surveys for other	400	300
	Subtotal	18,900	13,400
	Total	28,700	16,900

[a] Beginning in 2001, strategic surveys replaced the extensive and general regional surveys.

Source: USDA and USDI 2000: 417-419.

Table 8-6—Approximate expenditures of the Survey and Manage program 2001–2004

Fiscal year	Regional program	Predisturbance surveys	Total
		Thousand dollars	
2001	10,400[a]	—[b]	—
2002	8,300[a]	7,700[c]	16,000
2003	6,100[a]	—	—
2004	5,200[d]	—	—
Total	30,000	>7,700	>16,000

[a] Source: 2003 Survey and Manage annual report, p. 8: http://www.or.blm.gov/surveyandmanage/AnnualStatusReport/2003/S_and_M-2003.pdf

[b] Data unavailable in existing documentation.

[c] Source: USDA and USDI 2004a: 215 noted that the level of expenditure for fiscal year 2002 fell short of predicted costs owing to less predisturbance surveys that year and stated that the total spent for the program was $16 million. The 2003 Annual Report shows program costs at $8.3 million, so the predisturbance cost was calculated from the difference between total and regional costs.

[d] Source: Survey and Manage program expenditure spreadsheet. On file with: Forest Service, Pacific Northwest Regional Office, Portland, Oregon 97208.

ability of the SM program to develop science-based products (for example, management recommendations and survey protocols) for over 400 poorly known, taxonomically diverse species. This shortage of expertise was especially critical on some taxa such as mollusks and fungi. Shortage of expertise also affected ability to develop products within deadlines envisioned by original planners. Nevertheless, the early SM organization struggled successfully to develop these essential products and to initiate broad regional surveys.

In 1999, as agencies began the EIS process to redefine the SM mitigation (eventually resulting in the 2001 ROD), a new SM organization was established with permanent staff that was responsible for all aspects of program implementation. Permanent positions included a program manager, strategic survey coordinator, conservation planner, and annual species review coordinator. A team of four agency representatives continued to provide support for many tasks. Approximately 90 specialists from BLM and FS field units (totaling 35 full-time equivalents) worked on taxa teams to develop species-specific products and to conduct species evaluations. An interagency group of intermediate managers provided direct oversight and leadership, thus enabling more efficient policy and management decisions. This new organization and leadership support greatly improved the efficiency and effectiveness of the program.

Much of the complexity and process-laden aspects of the SM program grew from the enormous task of building a science-based approach for conserving 400 poorly known species that required gathering new information over a 24-million-acre planning area. Working across BLM and FS agency boundaries, both organizationally and physically on the landscape, added another layer of complexity. Many SM tasks such as development of management recommendations and protocols, database development and analysis, and species status evaluations, required regional oversight; other tasks such as conduct of preproject surveys and data collection were the responsibility of field units. Successfully implementing these tasks required new ways of communicating between agencies and between regional headquarters and district offices. In the end, the ability of agencies to cross these boundaries and overcome many of the challenges was perhaps one of the more successful aspects of the SM program, particularly after formation of the new SM permanent organization. Six federal agencies shared personnel and resources over several years to accomplish these many difficult tasks, thus meeting one of the primary goals of the Plan in working together to manage resources at a regional scale.

Several important lessons emerge regarding the organization of an effective science-based management conservation program. First, and most important, is having a long-term vision that clearly articulates both short- and long-term objectives for the program. Such a vision was lacking in the early years of SM implementation so it was difficult to pull together the complex tasks into a cohesive framework to measure success. Secondly, permanent expert staff assigned to the program provided continuity and accountability for meeting expectations far more efficiently than did staff temporarily assigned as detailers from other units. The SM program significantly enhanced its productivity and accountability with the development of a recognized program with permanent positions. The recent additions of new positions to the regional SSSSP is an important step in that direction. Third is development of effective communication between regional and field staff to provide timely information sharing of ongoing tasks, deadlines, and accomplishments. The SM Web site (www.or.blm.gov/surveyandmanage), annual reports, data calls, and field training workshops are good examples. Finally, connecting the program to a regional vision to conserve biodiversity would help to place the conservation of rare species in a broader agency mission context.

Bruce G. Marcot

Figure 8-9—This rare Survey and Manage species is Van Dyke's salamander (*Plethodon vandykei*), found mostly in southwest Washington.

Considerations

Efficacy of Large Reserves for Conservation of Rare Species and Biodiversity

A central tenet of the Plan was that the system of late-successional reserves would largely suffice to provide for species and biodiversity components associated with late-successional and old-growth forest ecosystems. We have found that, to an extent, this is likely true. However, the degree to which late-successional reserves–along with the set of other Plan land allocations (for example, riparian reserves in matrix lands)–suffice varies considerably by species and biodiversity component. It also likely varies by the specific locations chosen for the late-successional reserves–such as whether they happen to intersect unknown sites of particular species or communities, and if they happen to contain microenvironmental conditions and specific habitat elements used and selected by those species or communities (figs. 8-9, 8-10).

Initial findings (Turley 2004) of the random-grid survey study on SM species suggest that both Plan reserves and LSOG forests within and outside reserves may play key roles in providing habitat for many species. Out of a total 394 SM species targeted for survey in this study, sufficient data were gathered on 108 species (bryophytes, fungi, lichens, and mollusks) by which to determine degree of association with reserves and with LSOG. Of these 108

Bruce G. Marcot

Figure 8-10—Typical streamside habitat of Van Dyke's salamander on Gifford Pinchot National Forest in the southern Washington Cascade Mountains, being studied by research wildlife biologist Charlie Crisafulli.

species, 41 species had 10 or more detections. These results alone suggest that most of the 394 SM species were seldom if ever encountered during the random grid survey, and thus results of this study pertain largely to the more abundant species. Of the 108 species tested for association with reserves, only 2 species (2 lichens) were significantly or marginally statistically associated with reserves, and 5 species (1 bryophyte, 1 fungus, 3 lichens) with matrix lands; the rest of the species showed no association with either reserve or matrix lands (figs. 8-11, 8-12). Of the 108 species

Figure 8-11—A Survey and Manage species of lichen, *Lobaria pulmonaria*, "lungwort" or "lung lichen," so named because it reminded medieval European doctors of lung tissue. It grows on trees, shrubs, and mossy rocks in moist low- to mid-elevation forests mostly in coastal influence zones (McCune and Geiser 1997). It is used in Britain as an indicator species of undisturbed forest ecosystems.

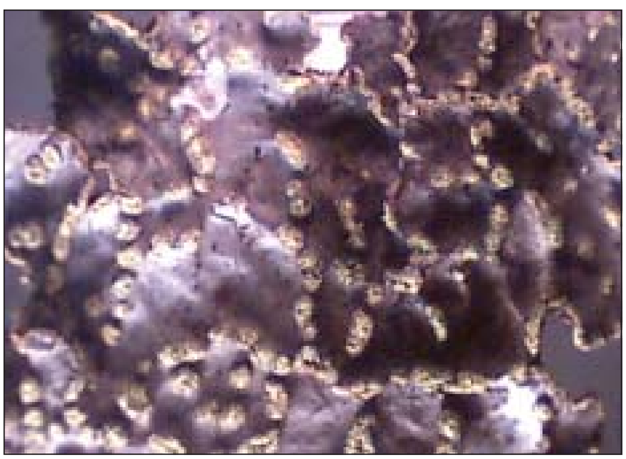


Figure 8-12—This Survey and Manage lichen is *Pseudocyphellaria crocata.* The round yellowish edges are structures called soralia, where algae enclosed in fungal threads are produced for asexual reproduction. This lichen grows on bark and wood of hardwoods in low- to mid-elevation forests in the western Cascade Mountains (McCune and Geiser 1997). The species is sensitive to, and can be used to indicate, air pollution.

tested for association with LSOG, 30 species (3 bryophytes, 6 fungi, 20 lichens, 1 mollusk) were significantly or marginally statistically associated with LSOG, and 1 species (1 lichen) with non-LSOG lands; the rest of the species showed no association with either LSOG or non-LSOG.

These results suggest that about one third of all species that could be tested (again, being the more abundant of the SM species) were marginally to closely associated with LSOG, but only one SM species showed such association with reserves. This provides evidence that LSOG is important for at least 30 SM species–which is useful information not available before the study. However, no information is available on most (73 percent) of the more rare SM species (286 species), which were not found or which were undersampled for statistical analysis.

For all SM species combined, reserves per se were not specifically selected for; over all species detections from this study, 81 percent were found in reserves, compared to 80 percent of the land base sampled being in reserves. Still, the data on 10 species selecting for reserves was new and significant information. Also, lack of association with reserves should not necessarily be construed as reserves not providing important habitat for species persistence, particularly for those species that do show association with LSOG. Late-successional and old-growth occurs in both reserve and matrix lands, and over time if LSOG regrows within reserves and is reduced in matrix lands, such a study as this could detect greater association with reserves per se.

In general, to maintain a large component of late-successional forest species and biodiversity elements, a reserve system may be viewed as a major "coarse filter" component, although additional "fine filter" evaluations and guidelines for some species and biodiversity elements also may be included (see below).

Recent Trends in Conservation of Biodiversity

Alternative approaches to biodiversity conservation and their efficacy for rare species conservation—
In the past decade, much has been written on methods and approaches to biodiversity conservation. A main focus has been on species conservation, with emphasis on maintaining or restoring viability of rare, declining, or listed species, although other dimensions of biodiversity besides individual species also have been addressed.

One example is the concept of coarse and fine filters in biodiversity conservation (Armstrong and others 2003, Reyers and others 2001). These terms have been used in a wide range of contexts but, in general, coarse filter refers to management of overall ecosystems and habitats and fine filter refers to management of specific habitats or sites for selected individual species. In a sense, the Plan follows this approach where the overall LSRs, riparian reserves, and guidelines for old-forest conservation and restoration constitute the coarse filter, and the SM program's focus on selected habitats and sites of rare species constituted the fine filter. The literature generally concurs that a combination of both coarse and fine filter elements better ensure conservation of a fuller array of species and biodiversity elements (Dobson and others 2001, Kintsch and Urban 2002). That is, applying just coarse-filter management of general ecosystems and habitats alone would not suffice to ensure conservation of all biodiversity elements including rare species associated with uncommon microhabitats and environmental conditions (Lawler and others 2003).

Another approach to biodiversity conservation has been delineation of hot spots of high species richness or of locations of endemic or at-risk species, and use of "gap analysis" to determine where such hot spots fail to coincide with conservation-oriented land allocations (Flather and others 1997, Root and others 2003). Reliability of hot spot locations and gap analyses depend on the accuracy of underlying species distribution maps. Some studies suggest that the hot spot approach alone does not necessarily ensure protection of rare species and that focus on a diverse set of species representative of a range of variation within ecological communities may be a more effective approach (Chase and others 2000).

Other recent approaches to biodiversity conservation have been devised to use many forms of surrogate species, such as umbrella species, management and ecological indicator species, flagship species, species functional groups, ecosystem functioning (for example, Hooper and others 2005), and others. Few of these approaches alone have proven fully reliable for ensuring conservation of rare species.

The conclusion is that, unless specifically targeted to address conservation requirements of rare species, alternative approaches to biodiversity conservation generally do not suffice to fully ensure persistence and protection of all rare species.

Monitoring of biodiversity—
The original ROD (USDA and USDI 1994b) called for effectiveness monitoring of biological diversity and late-successional and old-growth forest ecosystems. Beyond the species-specific owl and murrelet population studies and the surveys conducted of SM species, little information has been gathered on the ecology of these species. Even at the species level, little information has been gathered on ecosystem functions of rare and little-known LSOG species, including SM species, especially in terms of their contribution to overall ecosystem processes. However, such information would be very difficult to gather. Any effort to monitor biodiversity would do well to consider the specific utility of such information in guiding forest management, and selection of surrogate measures for difficult parameters used for adaptive forest planning.

Considerations in Developing Species Conservation Programs

Although the Plan was considered a science-based plan, there remained significant uncertainties and untested assumptions after implementation. This was particularly true for the SM program because this mitigation grew out of the uncertainty surrounding the viability of the species and how well the overall Plan (especially the reserve systems) provided for species persistence. Furthermore, most of the taxa listed for protection were rare or little known, so available science was meager on how best to conserve these species. These issues point to the benefits from partnering with research agencies and universities in developing the science basis for conservation programs. Indeed, some of the conservation issues may call for specific research approaches to develop new knowledge on specific areas of concern (for example, from understanding individual species ecology to developing landscape sampling designs). From experience gained we offer the following considerations:

Research partnerships—
- Consider including research partners in initial program design.
- Consider clearly defining the role of research in adaptive management and decision processes.
- Consider identifying specific information gaps and developing appropriate research studies to fill those gaps.

Coarse- vs. fine-filter approaches—
- Consider carefully defining what is meant by coarse and fine filter (that is, what elements these represent).
- Consider clearly laying out in your conservation program the contributions expected from these two approaches (for example, role of reserves and protecting specific sites).

Species viability and persistence—
- If these represent species management goals, consider clearly defining the terms and how you will measure obtaining that goal.

Value of metrics—
- Consider clearly designing metrics to meet specific objectives.
- Consider the limitations of surrogates (for example, indicator or focal species) for meeting broad conservation objectives.
- Consider validating the use of surrogates in meeting conservation objectives.

Database—
- Consider designing an effective database for data storage and analysis that will meet both short- and long-term objectives.
- Consider developing a robust database that is easy for diverse users to query.
- Consider the types of analyses that are required from the data.
- Consider adequately staffing this function to provide for quality stewardship and timely analyses.

Survey design—
- Consider developing a framework and process to strategically focus resources on key information gaps.
- Consider exploring a variety of survey approaches and analyze these for efficiencies in terms of cost and information gained.
- Consider the value that certain types of surveys provide or do not provide (for example, predisturbance surveys typically provide biased data on species distribution and abundance).
- Consider looking for efficiencies by designing surveys to include multiple species.
- Consider collecting information that is critical to meeting specific conservation objectives (for example, habitat information for modeling, species abundances for population considerations).
- Consider using statistically designed surveys when possible that allow for extrapolation of results to larger landscapes.

Habitat modeling—

- Consider exploring different habitat modeling approaches to meet specific conservation objectives.
- Consider the limitations of habitat modeling.

Decision support—

- Consider developing decision-support models that integrate relevant information.

Monitoring—

- Consider developing a monitoring framework that will enable you to measure how well you meet specific objectives (for example, species persistence, minimizing management effects, evaluating trends, etc.).

The Future

The Plan has been a remarkably ambitious effort designed, in part, to conserve a wide array of rare and little-known species across multiple taxonomic and ecological groups. Although the charge for the conservation of most species now falls into another program (SSSSP), lessons learned from the Plan on species responses and program implementation can help guide successful outcomes.

The broader expectations for demonstrating conservation of forest biodiversity elements beyond rare species, and the direction in the Plan to address biodiversity issues through effectiveness monitoring (Ringold and others 1999), however, still remain as mostly unmet challenges.

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Chapter 9: The Aquatic Conservation Strategy of the Northwest Forest Plan: An Assessment After 10 Years

Gordon H. Reeves

Introduction

The Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan (the Plan) is a regional strategy designed to restore and maintain the processes that create and maintain conditions in aquatic ecosystems over time across the area inhabited by the northern spotted owl (see appendix for species names). It seeks to prevent further degradation of aquatic ecosystems and to restore habitat and the ecological processes responsible for creating of habitat over broad landscapes, as opposed to individual projects or small watersheds (USDA and USDI 1994). The foundation of the ACS is a refinement of earlier strategies, "The Gang of Four" (Johnson and others 1991), PacFISH (USDA 1992), and the Scientific Assessment Team (Thomas and others 1993). Its primary objectives are to maintain and restore:

- The distribution, diversity, and complexity of watershed and landscape-scale features to ensure protection of the aquatic ecosystems to which species, populations, and communities are uniquely adapted.
- The spatial and temporal connectivity within and between watersheds.
- The physical integrity of aquatic ecosystems, including shorelines, banks, and bottom configurations.
- Water quality necessary to support healthy riparian, aquatic, and wetland ecosystems.
- The sediment regime under which the aquatic ecosystem evolved.
- Instream flows sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, nutrient, and wood routing.
- The timing, variability, and duration of flood plain inundation and water table elevation in meadows and wetlands.
- The species composition and structural diversity of plant communities in riparian zones and wetlands.
- Habitat to support well-distributed populations of native plant, vertebrate, and invertebrate riparian-dependent species.

In the short term (10 to 20 years), the ACS was designed to protect watersheds that currently had good habitat and fish populations (FEMAT 1993). The long-term goal (100 years) was to develop a network of functioning watersheds that supported populations of fish and other aquatic and riparian-dependent organisms across the Plan area (USDA and USDI 1994).

The ACS contains four components to meet these goals and objectives:

- Watershed analysis: Watershed analysis is an analytical process to characterize watersheds and identify potential actions for addressing problems and concerns and to identify possible management options. It assembles information necessary to determining the ecological characteristics and behavior of the watershed and to develop options to guide management in the watershed, including adjusting riparian reserve boundaries.
- Riparian reserves: Riparian reserves define the outer boundaries of the riparian ecosystem. They are the portions of the watershed most tightly coupled with streams and rivers. They provide the ecological functions and processes necessary to create and maintain habitat for aquatic- and riparian-dependent organisms over time, provide

dispersal corridors for terrestrial organisms, and to provide connectivity in a watershed. The boundaries were interim until a watershed analysis was completed, at which time they could be modified depending on suggestions made in the watershed analyses.

- Key watersheds: Key watersheds are intended to serve as refugia for aquatic organisms, particularly in the short term for at-risk fish populations, to have the greatest potential for restoration, or to provide sources of high-quality water. Tier 1 key watersheds currently have good populations or habitat, a high restoration potential, or both. Tier 2 key watersheds provide sources of high-quality water.
- Watershed restoration: Watershed restoration is designed to recover degraded habitat. Restoration activities focus on restoring the key ecological processes required to create and maintain favorable environmental conditions for aquatic and riparian-dependent organisms.

The ACS also includes standards and guidelines that apply to management activities in riparian reserves and key watersheds.

The primary objective of this chapter is to identify the expectations for the ACS in the first 10 years of implementation and to assess how well the ACS has met the expectations. Additionally, I will review the original scientific basis for the ACS and the relevant science produced since then.

Expectations and Results

Potential Listing of Fish Species and Evolutionarily Significant Units Under the Endangered Species Act

A primary motivation for developing the ACS was the anticipated listing of distinct population segments of various species of Pacific salmon, called evolutionarily significant units (ESUs), and other fish species under the Endangered Species Act (ESA 1973). When the Plan was developed in 1993, only the Sacramento winter chinook salmon, the shortnose sucker, and the Lost River sucker were listed. Since then, 23 ESUs of Pacific salmon and 3 population segments of bull trout found in the Plan area have been listed. Twenty units of salmon and all bull trout population segments are found on federal lands managed under the Plan (table 9-1). Additionally, the Oregon chub was listed after the Plan was implemented and coho salmon in the Oregon coast is currently a candidate for listing (table 9-1).


Michael J. Furniss

A coho salmon in Bell Creek, in the coastal lakes watershed (Oregon Coast Range) on the Siuslaw National Forest near Florence, Oregon.

The Plan was expected to contribute to the recovery of the ESA-listed fish, particularly the anadromous salmon and trout (that is, fish that spend their early life in freshwater, move to the ocean to mature, and then return to freshwater to reproduce), by increasing the quantity and quality of freshwater habitat (FEMAT 1993). It was not expected to prevent the listing of any species or distinct population segment. The primary reason for this expectation was that the federal land management agencies are responsible only for the habitat they manage; state agencies are responsible for populations on all lands and for the regulation of activities that affect populations and habitats on other ownerships. Factors outside the responsibility of federal land managers contribute to the declines of these populations and will strongly influence their recovery. These

Table 9-1—Evolutionarily significant units (ESUs) of Pacific salmon and trout (*Oncorhynchus* spp.), distinct populations segments (DPSs) of bull trout (*Salvelinus confluentus*), and fish species listed and candidates for listing (*) under the Endangered Species Act that occur in the area covered by the Plan

Species	ESU/DPS	National forests (NF) and Bureau of Land Management (BLM) districts where species occur
Coho salmon	Lower Columbia/southwest Washington	Gifford Pinchot NF, Mount Hood NF
	Oregon coast*	Siuslaw NF, Umpqua NF, Siskiyou NF, Eugene BLM, Coos Bay BLM, Medford BLM, Roseberg BLM, Salem BLM
	Southern Oregon/ northern California	Rogue River-Siskiyou NF, Six Rivers NF, Shasta-Trinity NF, Klamath NF, Mendocino NF, Arcata BLM, Kings Range National Conserva-ion Area (NCA), Redding BLM, Medford BLM, Coos Bay BLM
	Central California coast	Ukiah BLM
Chinook salmon	Puget Sound	Mount Baker-Snoqualmie NF, Olympic NF, Gifford Pinchot NF
	Lower Columbia	Gifford Pinchot NF, Mount Hood NF, Salem BLM
	Upper Columbia	Okanogan NF, Wenatchee NF
	Upper Willamette	Mount Hood NF, Willamette NF, Eugene BLM, Salem BLM
	California coastal	Six Rivers NF, Mendocino NF, Arcata BLM, Kings Range NCA, Ukiah BLM
	Sacramento River winter run	Mendocino BLM
	Central Valley spring run	Shasta-Trinity NF, Mendocino BLM, Redding BLM
	Central Valley winter run	Redding BLM
Chum salmon	Hood Canal summer	Olympic NF
	Columbia River	Salem BLM
Steelhead	Lower Columbia	Gifford Pinchot NF, Mount Hood NF, Salem BLM
	Mid-Columbia	Gifford Pinchot NF, Mount Hood NF, Wenatchee NF
	Upper Columbia	Wenatchee NF, Okanagon NF
	Upper Willamette	Willamette NF, Salem BLM, Eugene BLM
	Northern California	Six Rivers NF, Mendocino BLM, Arcata BLM, Ukiah BLM, Kings Range NCA
	Central California coast	Arcata BLM, Kings Range NCA
	Central Valley, California	Shasta-Trinity NF, Mendocino BLM
Coastal cutthroat trout	Southwest Washington/ Columbia River	Gifford Pinchot NF

Table 9-1—Evolutionarily significant units (ESUs) of Pacific salmon and trout (*Oncorhynchus* spp.), distinct populations segments (DPSs) of bull trout (*Salvelinus confluentus*), and fish species listed and candidates for listing (*) under the Endangered Species Act that occur in the area covered by the Plan (continued)

Species	ESU/DPS	National forests (NF) and Bureau of Land Management (BLM) districts where species occur
Bull trout	Klamath River	Winema NF
	Columbia River	Deschutes NF, Gifford Pinchot NF, Mount Hood NF, Wenatchee NF, Okanongon NF, Willamette NF, Eugene BLM
	Coastal-Puget Sound	Gifford Pinchot NF, Mount Baker-Snoqualmie NF, Olympic NF
Oregon chub		Willamettte NF, Umpqua NF
Lost River sucker		Winema NF
Shortnose sucker		Winema NF

include (National Research Council 1996):

- Degradation and loss of freshwater and estuarine habitats.
- Excessive harvest in commercial and recreational fisheries.
- Migratory impediments, such as dams.
- Loss of genetic integrity from the effects of hatchery practices and introductions.

Ocean productivity also strongly influences population numbers of anadromous salmonids. Conditions in the marine environment in the Plan area are highly variable over time. The oceanic boundary between cool, nutrient-rich northern currents and warm, nutrient-poor southern currents is off the coast of Washington, Oregon, and northern California (Fulton and LaBrasseur 1985) (fig. 9-1). The location of this boundary is influenced by the Pacific Decadal Oscillation (PDO), which is climatically driven and results in an oscillation between positive and negative phases every 20 to 30 years. This oscillation results in alternating regimes of salmon production between the Pacific Northwest and more northerly areas along the Pacific coast of North America (Mantua and others 1997). During periods of high productivity, zooplankton biomass—a critical food for salmonids when they first enter the ocean—is greater in the productive zone than in the less productive region. Early ocean survival of anadromous salmonids and the number of adults returning to freshwater are greater during the positive phases (Mantua and others 1997). The last period of high productivity was from the late 1940s to 1977 (Mantua and others 1997). The Plan area is currently in another positive production phase, but how long the current phase that began in 2001 will last is unknown.

Population numbers of many ESA-listed salmon and trout in the Plan area, and other parts of the Pacific Northwest, have increased since the Plan was implemented. However it is not possible to discern how much the Plan has contributed to this increase. Conditions of freshwater habitats on federal lands have improved moderately under the Plan (see later discussion for more details) but not to an extent that could account for the current increases in the numbers of returning adults. Populations in areas outside of the Plan area have shown similar, and even larger, changes.

The real contribution of freshwater habitats to the persistence and recovery of anadromous salmon and trout in the region covered by the Plan will be measured when the PDO moves into a less productive phase and the persistence of andromous salmon and trout populations will depend to a larger degree on freshwater habitat (Lawson 1993) (fig. 9-2). Improvements in the quantity and quality of

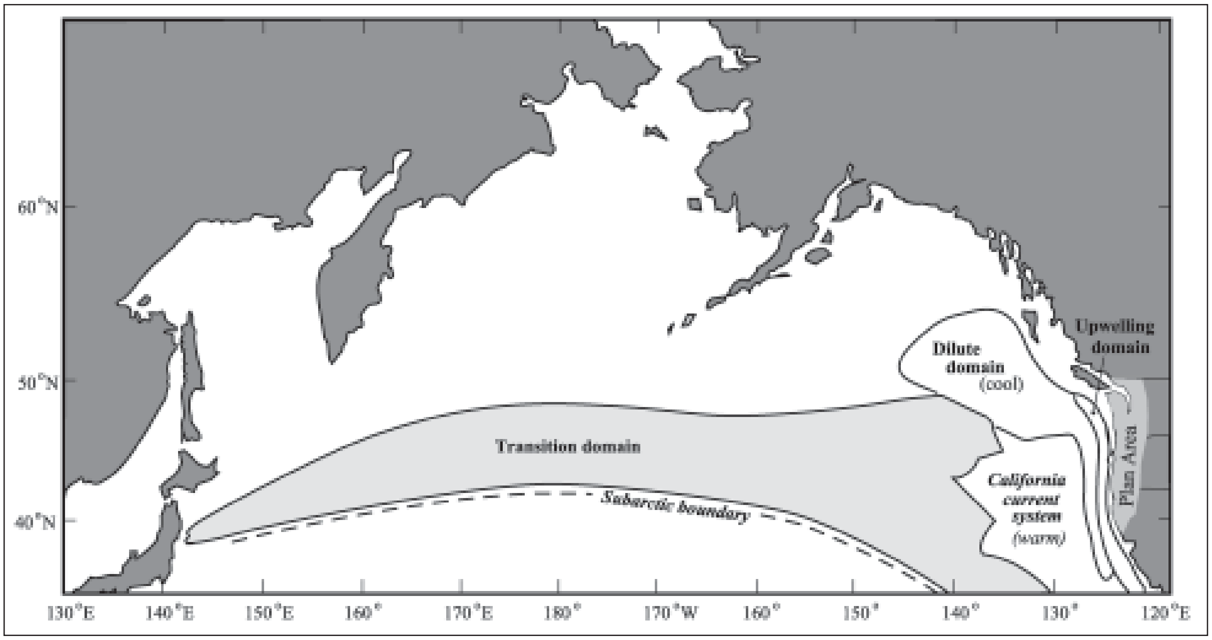

Figure 9-1—Boundaries of eastern north Pacific Ocean currents. Source: Fulton and LaBrasseur 1985.

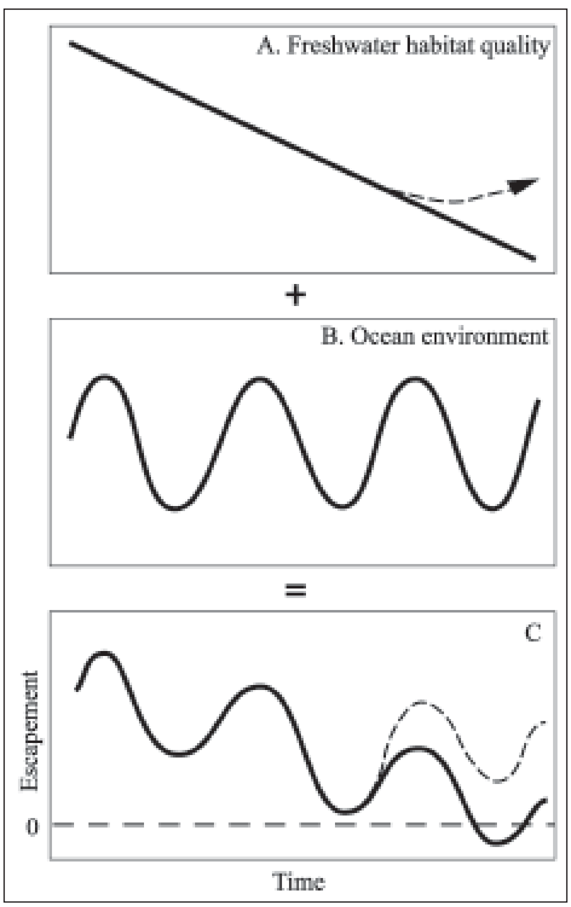

Figure 9-2—Conceptual relation between the quality of freshwater habitat, variable ocean conditions, and the persistence of populations of anadromous salmonids. "A" is the trajectory of habitat quality over time. Dotted line represents possible effects of improvement in habitat quality. "B" is the generalized time series of ocean productivity over time. "C" is the sum of the interaction of A and B. Source: Modified from: Lawson 1993.

freshwater habitat should result in greater numbers of fish entering the ocean, thus increasing the likelihood of persistence of many populations during periods of low productivity.

Changes in Watershed Condition

The ACS was designed to improve the ecological condition of watersheds in the Plan area over an extended time (that is, several years to decades). It is based on preserving key ecological processes and recognizes that periodic disturbances may be required to maintain ecological productivity. As a result, the ACS does not expect that all watersheds will be in good condition at any point in time, nor does it expect that any particular watershed will be in a certain condition through time. If the ACS and the Plan are effective, the proportion of watersheds in better condition is expected to remain the same or increase over time (Reeves and others 2004). However, the ACS does not identify a particular desired or acceptable distribution of watershed condition. It does, however, recognize that significant results from the ACS were not expected for several years or decades because it will take extended time for the condition of watersheds that were extensively degraded from past management activities to improve (FEMAT 1993).

The ACS attempts to improve watershed conditions by preserving key ecological processes.

Large improvements in the condition of individual watersheds or changes in the distribution of conditions were not expected in the short term (10 to 20 years) because this was too short a time for many watersheds to improve, and the impact of restoration efforts would not be extensive enough across the Plan area to result in discernable changes in the distribution of watershed conditions. At best, it was expected that the pattern of degradation would be slowed or halted, and there may be some minor to moderate improvements in watershed condition as a result of the implementation of the ACS.

A monitoring program to determine the effectiveness of the ACS was expected to be developed and implemented within a short time of the record of decision (ROD) (USDA and USDI 1994), but the Aquatic and Riparian Effectiveness Monitoring Program (AREMP) did not begin until 2000. This delay resulted from the difficulty that the relevant agencies (USDA Forest Service [FS], USDI Bureau of Land Management [BLM], the Environmental Protection Agency [EPA], and National Oceanic and Atmospheric Administration [NOAA] Fisheries) had with agreeing on an approach, much less an actual program. Before 2000, two attempts were made to develop an effectiveness monitoring plan that all agencies could support. Both attempts failed because the involved parties could not agree on a common vision for the plan, a common approach to the problem, or methodology. The need for three attempts to develop an effectiveness monitoring plan illustrates the struggle over the ACS because of differences in operating and thinking among the involved agencies. The AREMP was approved by the regional executives in 2000, and pilot testing began that year. Components of AREMP and the rationale for them are described in Reeves and others 2004.

The AREMP attempts to characterize the ecological condition of watersheds by integrating a set of biological and physical indicators, and it tracks the trend in condition of the population of watersheds over time. The condition of watersheds is evaluated with decision-support models by using fuzzy logic (Reeves and others 2004). The relations between the selected parameters and the watershed condition used in these models were based on empirical evidence and the professional judgment of aquatic specialists from the national forests, BLM districts, management and regulatory agencies involved with the Plan, and state fish management agencies. The models were built at the province and subprovince scales to account for ecological variability.

The condition of a watershed was defined as "good" if the physical attributes were adequate to maintain or improve biological integrity, primarily for native and desired fish species (Reeves and others 2004). Also, the systems that were in good condition were expected to be able to recover to desired conditions when disturbed by a natural event or land-management activities. Scores for watershed conditions ranged from 1 to -1: 1 if absolutely true (based on the assumptions in the decision-support model) that the watershed was in good condition, and -1 if absolutely false that it was in good condition. Reeves and others (2004) emphasized the need to recognize that condition of any watershed may vary widely naturally. For that reason, it was recognized that watersheds with little or no human activity were not necessarily in good condition at any point in time.

The focus of AREMP is not on individual watersheds but rather on the statistical distribution of watershed conditions across the Plan area. Two hundred fifty 6th-field watersheds (10,000 to 40,000 acres) were randomly selected from throughout the Plan area to be sampled over a 5-year cycle (Reeves and others 2004). The full range of management from roadless and wilderness to intensive timber harvest and livestock grazing were found in these watersheds.

Pilot testing in AREMP to evaluate sampling protocols and to determine funding and staff requirements occurred in 2000 and 2001. Actual monitoring began in 2002, with about half of the estimated funding needed to fully implement AREMP. Monitoring continued at reduced levels in 2003 and 2004. A total of 55 (of an expected 100) watersheds were sampled in 2002 and 2003 (Gallo and others 2005). No watersheds have been resampled to permit direct estimates of change in watershed condition.

The parameters necessary to estimate watershed condition—in-channel, upslope, and vegetation—were only available for 55 watersheds, and as mentioned above, none of these have been resampled (Gallo and others 2005). Lacking the ability to assess the total changes in watershed conditions in the Plan area, Gallo and others (2005) examined changes associated with riparian vegetation and the amount of roads in the 250 watersheds selected for sampling by AREMP. They calculated partial changes in watershed condition scores based on these parameters for two periods, roughly 1994 and 2003 (fig. 9-3). The distribution of these scores did not change to a statistically significant degree during this time (Gallo and others 2005). This result is not surprising given the relatively short period in which the ACS has been in place and that condition scores only represented a partial change.

The proportion of watersheds (of those that exhibited a change) that had a higher condition in 2003 than in 1994 compared to those with lower scores was greater than expected by chance alone ($P < 0.01$, Wilcoxon signed-rank test [Sokal and Rohlf 1969]). The changes in condition scores for individual watersheds are shown in figure 9-3. The condition scores of about 18 of the 250 remained the same, 161 improved, and 71 decreased between 1994 and 2003 (fig. 9-3). The average changes in scores were relatively small, 0.09 (SD 0.19) for those that increased and 0.14 (SD 0.3) for those that decreased. The decreases in watershed condition scores were not simply related to management activities; the four watersheds that exhibited the largest decline had 30 to 60 percent of the watershed area burned.

The observed changes suggest some progress owing to the ACS. The ecological significance of this progress is not known, however. An understanding of the relation between changes in watershed scores is not established as yet. Also, because there are multiple factors influencing watershed condition, a change in score can occur from a combination of changes in the factors. This is certainly an area that lacks research.

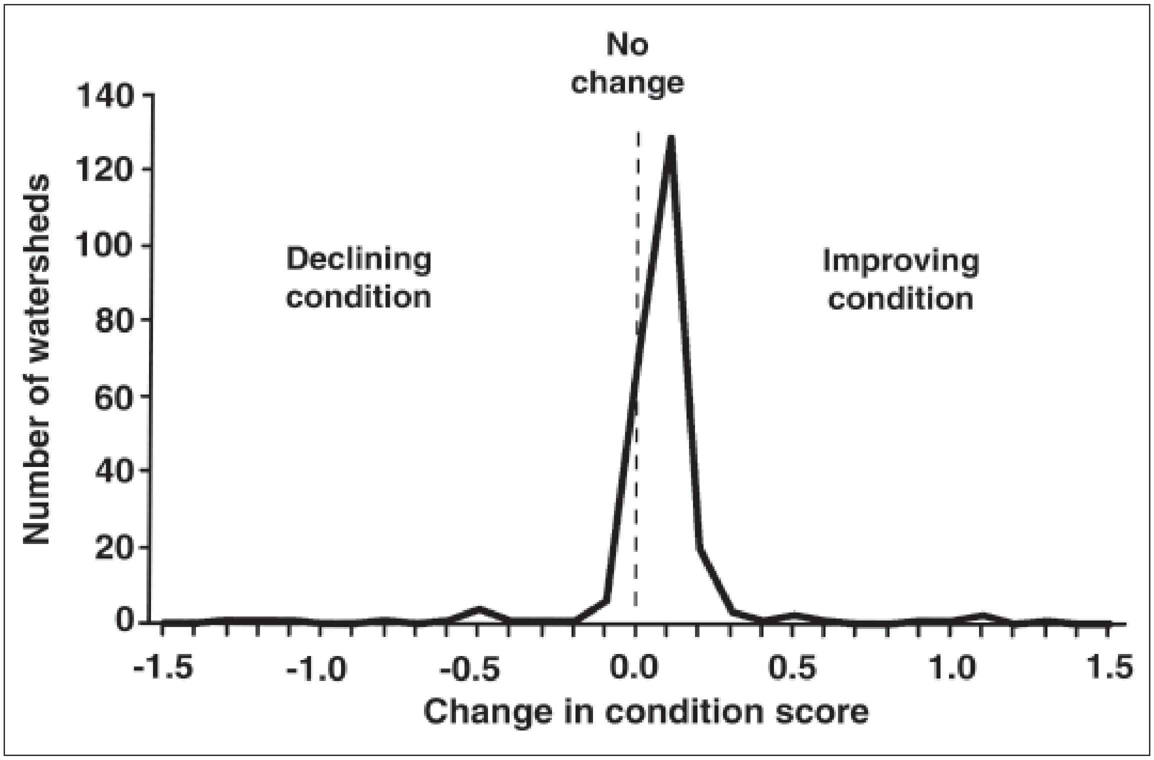

Figure 9-3—Changes in condition scores for 250 watersheds sampled as part of the aquatic and riparian effectiveness monitoring program of the Plan. Source: Gallo and others 2005.

The change in watershed condition scores during the first decade of the Plan was attributable primarily to changes in riparian vegetation and, more specifically, an increase in the number of large trees in riparian areas. The type, size, and distribution of vegetation in riparian and upslope areas influence the condition of aquatic ecosystems (Burnett 2001); generally, the bigger and more numerous the conifers the better the condition of the watershed. Gallo and others (2005) compared the number of trees >20 inches diameter at breast height (d.b.h.) in riparian (defined in the ACS as 150 feet on both sides of the stream on the west side of the Plan area and 90 feet on the east side) and upslope areas in the 250 watersheds in 1996 shortly after the Plan was implemented and in 2002. They used the geographic information system (GIS) layers developed by the Interagency Vegetation Mapping Project (IVMP) for Oregon and Washington and CalVeg for California, which were used to assess changes in late-successional and old-growth habitat (Moeur and others 2005). The number of large trees increased an estimated 2 to 4 percent during this time, most likely the result of tree growth into the >20-inch d.b.h. category (Gallo and others 2005). Concurrently, the amount of riparian area subjected to clearcutting on federal lands in Oregon and Washington in the Plan area was one-seventh the level of harvest in 1988-91 and even less compared to earlier periods (Gallo and others 2005). Projections of tree size on federally managed lands in the central and northern Oregon Coast range suggest that the number of large trees will continue to increase by 15 to 20 percent over the next 100 years under the current policy (Burnett and others, in press; Spies and others, in press).

Roads, permanent and temporary, can significantly affect aquatic ecosystems. They can result in increased rates of erosion (Furniss and others 1991, Potondy and others 1991), which, in turn, may affect populations of fish and other aquatic organisms (Quigley and Arbelbide 1997, Young and others 1991) and their habitats (Buffington and others 2002, Megahan and Kidd 1972). They can also form barriers to movements and can reduce interactions within and among populations of fish, amphibians, and other aquatic organisms (Trombulak and Frissell 1999).

The condition scores of watersheds as influenced by roads generally did not change significantly since the Plan was implemented (Gallo and others 2005). Three of the watersheds that had the largest increase in condition scores had the most extensive road decommissioning efforts (Gallo and others 2005). It is likely in the other cases that the amounts of road removed from any given watershed may have been relatively small and insufficient to change the watershed condition. There were 3,324 miles of road (3.6 percent of the total road mileage) decommissioned from 1995 to 2002 on FS and BLM lands (Baker and others, in press). An estimated 354 miles of new roads were constructed during the same time (Baker and others, in press). The effect of roads on aquatic ecosystems is also a function of road location; valley bottom roads affect aquatic ecosystems more than those on ridgetops (Wemple and others 2001). The provincial and subprovincial models that evaluate watershed condition differed widely in how they considered road location; some consider location, whereas others only consider the density of roads. Modification of those that currently do not consider road location may increase their sensitivity to restoration activities.

Several miles of roads have been "improved"—that is, actions were taken to reduce sediment delivery and improve stability or to allow more natural functioning of streams and flood plains, which includes improvements in drainage, stabilization, and relocation (Baker and others, in press). However, the watershed condition models currently do not take this into account because road improvement data are currently not available in the federal agencies' corporate databases.

Assessment of the ecological condition of an individual watershed was done on the basis of the entire landscape, which resulted, in many instances, in considering conditions on nonfederal lands. In many of the watersheds sampled by AREMP, there were a number of different owners, each with objectives and practices that differed from those of the Plan. Watersheds with more nonfederal ownership had the lowest changes in watershed condition scores (Gallo and others 2005). This influences the potential amount of change that can be expected in some watersheds and could be considered in future assessments of the effectiveness of the ACS.

One clear success of the ACS is a change in the general expectation of trends in aquatic conditions across the Plan area. There is general recognition that aquatic conditions deteriorated during the pre-Plan periods of intensive federal timber harvest and road building, and these declines were predicted to continue under many of the forest plans that the Plan amended. Several forest plans that were to be implemented before the Plan acknowledged that aquatic habitat would decline (for example, the Siuslaw National Forest [NF]) or have a high probability of declining (Umpqua NF, Siskiyou NF). Many of the activities that could have had negative effects on aquatic ecosystems, however, have decreased under the Plan. As cited earlier, the amount of timber harvest in riparian areas decreased substantially (Gallo and others 2005). Implementing the ACS appears also to have influenced the rate at which roads were built in the Plan area. The amount of roads decommissioned was 10 times the amount built between 1995 and 2002, the reverse of the trend before the Plan (Baker and others, in press). The ACS and the Plan appear to have prevented further degradation of watersheds that was likely under previous forest plans.

Riparian Reserves

The riparian reserve network established by the ACS encompasses an estimated 2.6 million acres (Baker and others, in press) and was one of the major changes from previous forest plans. Before the ACS, the riparian ecosystem was generally defined as 100 feet on either side of fish-bearing streams and some areas with high landslide risk. The riparian reserve network of the ACS was based on an "ecological functional" approach that identified zones of influence rather than set distances and included the entire stream network, not just fish-bearing streams. Consequently,

Example of how riparian habitat extends from the edge of a stream.

the riparian zone along streams was expanded to the height of two site-potential trees (or 300 feet) along fish-bearing streams and one tree height (or 150 feet) along permanently flowing and intermittent non-fish-bearing streams (USDA and USDI 1994). The latter undoubtedly contributed the greatest to the increased amount of area considered as the riparian reserve. More than 800 of the more than 1,100 organisms considered in FEMAT (1993) were found to be associated with the riparian reserve network. It was also suggested in FEMAT (1993) that the width of the riparian reserve on each side of headwater streams be equal to one-half the height of a site-potential tree, but it was changed to a full tree height in the ROD (USDA and USDI 1994) to increase the likelihood of persistence of habitat for aquatic and riparian-dependent organisms.

The initial riparian reserve network was expected to be interim, and activities within them were very restricted until a watershed analysis was completed. It appears, however, that the interim boundaries of the riparian reserves remained intact in the vast majority of watersheds (Baker and others, in press). The primary reasons offered for the relatively low harvest in the riparian reserve were that it was difficult to justify changing the interim boundaries or that there was no compelling justification for changing the interim boundaries. (It should be noted that harvest from the riparian reserve was not part of the estimates of potential timber harvest.) Baker and others (in press) found that agency personnel thought that "burden of proof [for changing interim boundaries] was too high." No explicit criteria for changing the boundaries were offered by the Forest Ecosystem Management Assessment Team (FEMAT 1993) or the ROD (USDA and USDI 1994), but tools are available now that can help identify the more ecologically important parts of the riparian and stream network from an aquatic perspective (such as Benda and others, n.d.). Because watershed analysis is an interdisciplinary endeavor, however, changes in the riparian reserve boundaries need to consider non-aquatic factors such as terrestrial and social concerns. Only a few watershed analyses considered these factors (such as Cissel and others 1998). The effect of the extent of the riparian reserves is probably most likely in the steeper more highly dissected landscapes, where the riparian reserves network is most extensive (FEMAT 1993).

Timber production, primarily in precommercial thinning, has occurred on an estimated 48,000 acres (1.8 percent of the estimated total area) of the riparian reserve (table 9-2). The volume of timber harvested is not known because agencies do not track it. Timber harvest was expected to occur in riparian reserves, but no level was specified by FEMAT (1993) or the ROD (USDA and USDI 1994). Harvest from the riparian reserve was not part of the estimated potential sale quantity of the Plan. Agency personnel thought that one of the primary reasons for the limited timber harvest in the riparian reserve was the difficulty in changing boundaries and in determining that there would be no adverse affects from the activities (Baker and others, in press).

Watershed Restoration

Watershed restoration efforts were expected to be a catalyst for initiating ecological recovery (FEMAT 1993). It was expected that restoration efforts would be comprehensive, addressing both protection of existing functioning aspects of a watershed and restoration of degraded or compromised aspects. It was recognized that it may not be possible for restoration efforts to restore every watershed or that some

Table 9-2—Estimated area of riparian reserve in which silvicultural activities have occurred during the first 10 years of the Plan

Administrative unit	Period	Treatment: Precommerical thin	Treatment: Regeneration harvest	Total
		———— *Acres* ————		
USDA Forest Service				
Region 6				
Mount Baker-Snoqualamie	1994-2000	1,100	0	1,100
Okanogan-Wenatchee	1994-2000	875	300	1,175
Gifford-Pinchot	1994-2004	600	0	600
Olympic	1994-2004	1,100	1,100	2,200
Mount Hood	1998-2004			1,200[a]
Deschutes	1997-2004	700	0	700
Willamette	1994-2004	6,600	125	6,725
Siuslaw	1994-2004	1,285	12,570	13,855
Umpqua	1994-2004	2,200	300	2,500
Siskiyou-Rogue River	2000-2004	1,902	0	1,902
Fremont-Winema	2003	0	0	400[b]
Estimated total		16,362	14,395	32,357
Region 5				
Klamath	1994-2004	4,598	781	5,379
Shasta-Trinity	1994-2004	1,701	515	2,216
Six Rivers	1994-2004	3,288	516	3,804
Mendocino	1994-2004	0	0	0
Estimated total		9,587	1,812	11,399
Bureau of Land Management				
Oregon-Washington				
Salem	1995-2003			797[b]
Coos Bay	1995-2003			1,326[b]
Eugene	1995-2003			520[b]
Roseburg	1995-2003			827[b]
Medford	1995-2003			663[b]
Estimated total				4,133
California				
Arcata	1995-2004	84	0	84
Ukiah	1995-2004	0	0	0
Estimated total		84		84
Estimated total				47,973

[a] Estimate was of 100 to 200 acres per year with no breakdown of treatment type.

[b] No breakdown of treatment type provided.

would only have limited success because of the extensive level of degradation. The impact of restoration efforts was not expected to be large or to be immediately visible. At the watershed scale, it may take an extended time to observe the effect of the restoration effort. The aggregate effect of watershed restoration effort, particularly those done during the initial phases of the ACS, may not be observable at the regional scale. Although it may appear that relatively large amounts of area have been restored, the reality is that this represents a small part of the total area that is degraded.


Paul Burns

A restoration project on Fiddle Creek (Siuslaw National Forest) where a portable yarder was used to pull logs into the creek from surrounding mature Douglas-fir stands to enhance spawning and rearing habitat for coho salmon.

It is not possible to accurately assess the regional effect of the numerous restoration efforts undertaken as part of the ACS. Gallo and others (2005) highlighted several watershed restoration efforts that were successful, but their impact cannot be discerned at the regional scale. The length of streams restored or made assessable to fish is also a relatively small fraction of the totals. However, the watersheds that had the largest improvement in condition scores were three that had relatively extensive road restoration programs (Gallo and others 2005). Similarly, Baker and others (in press) reported that almost 69,000 acres of riparian reserve were restored, primarily in Washington and Oregon, between 1998 and 2003. The total amount of area in riparian reserve in this area is not known, but the 69,000 acres represents a relatively small part (estimated at about 2.6 percent) of total area occupied by the riparian reserve. It is expected that as time passes, the effect of these restoration efforts that have been implemented already and those that may occur in the future will be more discernable.

Key Watersheds

Key watersheds (1) are intended to serve as refugia for aquatic organisms, particularly in the short term for at-risk fish populations; (2) have the greatest potential for restoration; or (3) provide sources of high-quality water (USDA and USDI 1994). Tier 1 key watersheds serve one of the first two purposes. These include 141 watersheds covering 8.1 million acres. Tier 2 key watersheds provide sources of high-quality water and include 23 watersheds covering about 1 million acres. Key watersheds were aligned with late-successional reserves as closely as possible to maximize ecological efficiency (USDA and USDI 1994) and to minimize the amount of area in which timber harvest activities were restricted.

A primary objective for the Tier 1 key watersheds was to aid in the recovery of ESA-listed fish, particularly in the short term (FEMAT 1993). Refugia that are areas of high-quality habitat and contain remnant populations are a cornerstone of conservation strategies. Past attempts to recover fish populations were generally unsuccessful because the focus was on fragmented areas of good habitat in stream reaches and not on a watershed perspective (Moyle and Sato 1991, Naiman and others 1992, Williams and others 1989). Tier 1 key watersheds currently in good condition were assumed to serve as anchors for potential recovery of depressed populations. Tier 1 key watersheds that had degraded conditions were judged to have the greatest potential for restoration and therefore become future sources of good habitat.

Key watersheds had greater increases in condition scores than did non-key watersheds (Gallo and others 2005). More than 70 percent of the key watersheds improved, whereas less than 50 percent of the non-key watersheds improved. The primary reason was that more than twice as many miles of roads were decommissioned in key watersheds compared to non-key watersheds. This result suggests that land management agencies appear to have treated key watersheds as priority areas for restoration, as stated in the ROD (USDA and USDI 1994).

Key watersheds were originally selected based on the professional judgment of fish biologists from the national forests and BLM districts covered by the Plan. No formal evaluation of the potential effectiveness of the network was conducted when the Plan was developed or since it was implemented. Fish populations in need of attention are clearly identified now, and it would be useful to see if the current system is beneficial to those fish in terms of the overall distribution as well as the suitability of individual watersheds.

New techniques are now available to aid in this assessment. For example, Burnett and others (2003) have developed a process to identify the potential of a watershed or stream reach to provide habitat for coho salmon and steelhead based on topographic features. In an analysis of a portion of the northern Oregon Coast Range, areas with the highest potential to provide habitat for coho salmon, an ESA candidate species, were primarily on private lands and for steelhead, which is not a listed species, on public lands. Analysis of Oregon State, BLM, and FS Pacific Northwest Region (R6) Forest Service Lands in the Oregon Coast Range (Peets and Doelker 2005) found that about 10 percent (155 miles) of the area with the best potential to provide habitat for coho salmon was on federally managed lands. A relatively small proportion of this habitat is found in key watersheds. Similar analyses in other areas could help determine the current effectiveness of the key watersheds.

Watershed Analyses

Watershed analysis was intended to provide the context for management activities in a particular watershed. It was to serve as the basis for developing project-specific proposals and determining restoration needs. It was envisioned in the ROD (USDA and USDI 1994) as analysis to involve individuals from the appropriate disciplines but not a decision-making process. The management agencies were expected to complete a watershed analysis before activities (except minor ones) were started in key watersheds and riparian reserves (USDA and USDI 1994b). The version of watershed analysis advocated in the Plan differed from the versions of watershed analyses that were used at the time (such as the Washington Forest Practices Board 1993) in that it involved disciplines and issues other than aquatic ones. Since the ROD (USDA and USDI 1994), several publications have examined the watershed analysis process and framework (Montgomery and others 1995, Reid 1998), but these analyses have been primarily from an aquatic perspective. A more comprehensive review and evaluation of watershed analyses could help improve processes and likely reduce costs while increasing the usefulness of the product.

Baker and others (in press) estimated that 89 percent of the watersheds (of a total of 550 watersheds) in the Plan area had completed watershed analyses by 2003 and that some unknown proportion of them had been revised at least once. This percentage seems high, given budget and personnel constraints that the land management agencies have faced. No formal assessment of watershed analyses has been done, but their quality and effectiveness likely differ widely. There is also the opportunity to reexamine the watershed analyses process to see if it can be conducted more efficiently and include not just a focus on the watershed of interest and what happens there but the context of the watershed in the basin. The latter is particularly relevant for the Plan to be implemented at a landscape scale.

Relevant New Science Information

Landscapes and Dynamic Ecosystems

The ACS was based on the best science available at the time. Much scientific literature on aquatic ecosystems, on the effects of human activities on them, and on conservation strategies for fish and other aquatic and riparian organisms has been produced since the Plan was implemented in 1994. Key science findings on the ecosystem and landscape dynamics and the historical range of variation (HRV) and on the ecological role of headwater streams are summarized here. These topics relate to ACS components and are particularly relevant to assessing the validity of the ACS components and other parts of the Plan and for considering future modifications. Not all of the relevant scientific literature is summarized or reviewed here. Documents that provide excellent reviews and synthesis on these and other relevant topics include Spence and others (1996), Naiman and Bilby (1998), National Research Council (1996), Gresswell (1999), and Everest and Reeves (in press.).

The ACS combined ecosystem and landscape perspectives to forge a management strategy that could be applied over broad heterogeneous areas. Before the ACS was developed, much of the management and research focus for fish ecology and conservation was on relatively small spatial scales, such as habitat units (Bisson and others 1982, Nickelson and others 1992) and reaches (Murphy and Koski 1989). At these scales, the needs of individual fish or communities are the primary interest. Williams and others (1989) found that no fish species listed under the ESA was ever recovered after listing and attributed this failure to the general focus of recovery efforts on habitat attributes rather than on restoring and conserving ecosystems. Thus, the developers of the ACS believed that shifting the focus to larger scales was necessary to aid in the recovery of freshwater habitats of listed and declining populations of anadromous salmon and trout and other fish in the range of the northern spotted owl. Since the ROD was approved (USDA and USDI 1994), a variety of sources, including interested citizens, interest groups, scientific review and evaluation groups (such as the Independent Multidisciplinary Scientific Team 1999, National Research Council 1996), regulatory agencies, and policy- and decisionmakers have called for developing policies and practices to manage the freshwater habitats of at-risk fish at ecosystem and landscape scales.

Understanding the differences and relation between scale and ecological organization is critical to implementing and evaluating the ACS. Allen and Hoekstra (1992) proposed a framework that emphasizes the role of the observer in choosing a scale of observation and deciding how to conceptually organize the parts and processes. By **scale**, they mean spatial or temporal extent. In contrast, **organization** is a subjective or definitional construct that invokes implicit, user-defined criteria. Ecological organization, such as ecosystem, landscape, or population, has meaning without any reference to a particular scale. For real-world management issues, both scale and organization should be made explicit. The intersection of the two creates a clear conceptual boundary that allows discourse and management to proceed.

Ecosystems and landscapes are levels of organization that are especially important within the ACS. Of the two, landscapes are the most tangible in that spatial proximity is the organizing principle (Allen and Hoekstra 1992), and the components of the landscape (such as forest stands, streams, clearings, roads, and so on) are readily apparent to human observers. From an aquatic perspective, the landscape of interest can be quite large and include multiple watersheds (Reeves and others 2002, 2004) but spatial patterns (that is, landscape attributes) can also be important at smaller scales. In contrast to landscapes, ecosystems are organized around the interaction between physical and biological components. The processes and material flows that are the substance of the ecosystem organization may be difficult to observe. Reeves and others (2002, 2004) used the directional flow of water to define aquatic ecosystems, and bounded their spatial extent by using watersheds, defined by FEMAT (1993) as subbasins of 20 to 200 square miles.

In conventional terms, ecosystem management often refers to managing large geographic areas, which has contributed to the confusion between ecosystems and scale. Lugo and others (1999) reiterated the major paradigms of ecosystem management, including:

- Ecosystems are not steady state but are constantly changing through time.
- Ecosystems should be managed from the perspective of resilience, as opposed to stability.
- Disturbance is an integral part of any ecosystem and is required to maintain ecosystems.

Clearly, these principles are not tied to a particular scale and would apply equally well to a single watershed and to a region.

Ecologists and managers recognize the dynamic nature of terrestrial ecosystems and how the associated biota and physical characteristics change through time. They are also aware that the range of conditions an ecosystem experiences is determined to a large extent by the disturbance it experiences (such as wildfire, hurricane, and timber harvest and associated activities). Natural disturbances can increase biological diversity, be crucial for the persistence of some organisms and the habitat that support them, and express and maintain key ecological processes (Turner and others 1994). Disturbances invariably involve a disruption in existing connections among ecosystem components, which leads to the release of nutrients and other materials and the potential for reorganization (Holling 1992). Resilience is the ability of an ecosystem to recover after a disturbance (Lugo and others 1999). An ecosystem demonstrates resilience after a disturbance when the environmental conditions after the disturbance are within the range of conditions that the system exhibited before the disturbance. Reduced resilience may result in both the extirpation of some species and increases in species favored by available habitats (Hansen and Urban 1992, Harrison and Quinn 1989, Levin 1974).

Given the role of disturbance in ecosystem dynamics, it is reasonable to expect ecosystems to be most resilient to the types of disturbance under which an ecosystem developed. Thus, one approach to minimizing management impacts is to make the combination of management actions and natural disturbance resemble the natural disturbance regime as closely as possible (Lindenmayer and Franklin 2002). Factors considered in developing ecosystem management plans and policies include the frequency, magnitude (Hobbs and Huenneke 1992, White and Pickett 1985), and legacy (that is, the conditions and materials that exist immediately following the disturbance) (Lindenmayer and Franklin 2002, Reeves and others 1995) of disturbance regimes in managed ecosystems. The effects of land management on the ecosystem depend on how closely the management disturbance regime resembles the natural disturbance regime with regard to these factors. Everest and Reeves (in press) reported they found little evidence or studies in the peer-reviewed literature of fish populations or habitat responding positively to or remaining unchanged as a result of intensive land management activities.

Landscape management strives to maintain a variety of ecological states in some desired spatial and temporal distribution. Management at that scale addresses the dynamics of individual ecosystems, the external factors that influence the ecosystems that compose the landscape, and the dynamics of the aggregate of ecosystems (Concannon and others 1999). To do this, landscape management could consider developing a variety of conditions or states in individual ecosystems within the landscape and the pattern resulting from the range of ecological conditions that are present (Gosz and others 1999). The specific features of the ecological states and their temporal and spatial distribution will vary with the objectives for a given landscape.

Scientists and managers have worked in concert to try to develop tools and techniques to facilitate landscape management. One such approach relies on HRV, which is conditions that a level of organization experiences naturally over an extended time, from several decades to centuries. The term is often used for individual components of an ecosystem, such as the number of pieces of large wood or number of pools, or for ecological states. The usual manner for establishing the HRV for a component of interest is to

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Streams with the greatest diversity of juvenile salmonids can be in midsuccessional forests.

measure the parameter in pristine systems (systems with little or no history of effects from human activities). The HRV is represented by the distribution of these values. This range is well established for terrestrial systems (early-, mid-, and late-successional) (for example, Wimberly and others 2000), but it is not incorporated into aquatic ecology.

Spatial scale is an important, but not well recognized, element of the HRV. The HRV is generally inversely related to spatial scale (Wimberly and others 2000) because it represents the range of average condition for the area. The smaller the spatial scale, the larger is the HRV and, conversely, the larger the scale, the smaller the HRV. Hierarchy theory provides the rationale for this relation and is an appropriate framework for considering ecosystem issues at and between different spatial scales (Overton 1977). Each level in the hierarchy of an ecosystem has unique properties and behaviors that are expressed over time. The properties of lower levels of organization are “averaged, filtered, and smoothed” as they are aggregated at higher levels of organization (O’Neill and others 1986). Consequently, the range and variability in the properties and conditions of the system are relatively wide at lower levels of organization compared to higher levels (Wimberly and others 2000). A recent paper on the concept of HRV (Landres and others 1999), and another estimating HRVs (Keane and others 2002) did not consider the effect of spatial scales.

Wimberly and others (2000) illustrated the HRV of successional vegetative stages in the Oregon Coast Range at multiple spatial scales. They estimated (based on a model of fire frequency and intensity and vegetation response over 3,000 years) that, at the scale of a late-successional reserve (100,000 acres), the range in the amount of old growth was from 0 to 100 percent. For an area roughly the size of a national forest (750,000 acres), the HRV for old-growth was from about 10 to 75 percent. The HRV for the Coast Range (5,600,000 acres) was 30 to 55 percent. The large, infrequent disturbance events generally affect relatively small portions of the landscape at any one time. Thus, having the entire area affected by a disturbance event at the same time is highly unlikely. The asynchronous nature of the disturbance events results in a series of patches of vegetation of different ages. This narrows the HRV because of the reduced likelihood of finding the entire area either with no or all old-growth at any particular time. The HRV is further reduced at larger spatial scales because disturbance events are even more desynchronized. Consequently, the range and variability in the properties and conditions of the system are relatively wide at lower levels of organization compared to higher levels (Wimberly and others 2000).

Spatial scale and implementation problems—
The developers of the Aquatic Conservation Strategy (FEMAT 1993) and the ROD (USDA and USDI 1994) did not fully recognize the implications of shifts to the landscape scale of the Plan and the ACS and its objectives, which has led to much confusion with the ACS objectives. The land management and regulatory agencies initially attempted to meet all of the ACS objectives for any action, which led to many problems and was the impetus for the final environmental impact statement (FSEIS) that clarified the intent of the ACS (USDA and USDI 2003). The objectives provide a framework for managing aquatic ecosystems at multiple spatial scales, but they became a checklist to evaluate the acceptability of any proposed action at the site scale. The objectives were not intended to be a hard set of criteria that could be applied equally at

each spatial scale of concern. This application was technically impossible because the objectives include a range of spatial scales, and the relation among scales was not considered. For example, objectives 1, 2, and 9 (listed on page 1) deal with landscape and regional objectives. The others deal with ecosystems. Determining consistency with the ACS at the site or small watershed scale is not as simple as assuming that all sites or small watersheds need to be in “good” condition at all times and that any actions that “degrade” a site or small watershed violates the ACS objectives. Conditions at the small scale range widely over time. The overriding objective is to have a mix of conditions at the broader scale, which requires that individual sites each exhibit a range of conditions over time.

Consistency at the small scale (site or subwatershed) is determined by the range of variability established at the larger scales (watershed or basin). The range of variability at the larger scales is the frequency distribution of conditions at the smaller scale that support acceptable amounts of habitat for populations of fish and other aquatic organisms. Watershed analysis was expected to establish the range of variability at the different scales, which was to be used to determine if proposed actions were consistent with the ACS. The focus of watershed analyses, however, has been primarily on the watershed; they fail to provide the context of the watershed in the larger landscape.

The recent supplemental FSEIS that clarifies the original intent of the ACS (USDA and USDI 2003) discusses the importance of considering multiple scales. Dealing with this issue is important if the ACS is to succeed.

Dynamics and aquatic ecosystems—
The perspective that aquatic systems are dynamic, particularly at the ecosystem and landscape scales, was not widely recognized, and no time was left to work out the implications when the ACS was developed. Before it was developed, a small number of researchers recognized that biotic (Resh and others 1988) and physical (Swanson and others 1988) components of aquatic systems, particularly at the smaller spatial scales, were influenced by relatively infrequent events, such as floods. One reason for the absence of the recognition of dynamics of aquatic ecosystems is that the major paradigms that shape our thinking about aquatic systems, such as the River Continuum Concept (Vannote and others 1980), do not consider time or its influence. Similarly, classification schemes such as that of Rosgen (1994) identify a single set of conditions for a given stream or reach type; how these conditions may vary over time is not considered. The physical and biological relations were assumed to be fixed in time and to be unchanging. From this perspective, watershed processes were assumed to be continuous and predictable, implying that the biophysical changes along the riverine network were easily predictable and modeled (for example, Newbold and others 1982, Vannote and others 1980).

Frissell and others (1986) described the hierarchical organization of aquatic ecosystems and identified a temporal component associated with each spatial scale; the finer the scale, the shorter the response period. However, they did not consider how features of a given level in the hierarchy respond over time. A more recent examination of the hierarchical organization of streams by Fausch and others (2002) also recognized that time is a critical factor to consider when examining aquatic ecosystems. They did not integrate time into their description of stream systems, however. The failure to incorporate time into consideration of aquatic systems, especially at higher levels of organization, has led to an implied expectation that stream ecosystems experience a limited, if not a single, set of conditions and that this condition is relatively stable through time.

The foundation for the ACS focus on ecological processes and dynamics came from Naiman and others (1992). They hypothesized that different parts of a watershed (headwaters, middle portion, and lower portion) had different disturbance regimes, based on the frequency and magnitude of disturbance. They also believed that the landscape would have watersheds with a range of conditions because of the asynchronous nature of large and infrequent disturbance events, such as wildfire and flooding. More recent studies have proposed that stream systems are complex networks with branched shapes rather than linear systems, which provides a better understanding of the ecological processes that link riparian and aquatic ecosystems (Benda and others 2004, Fisher 1997). This perspective implies that aquatic ecosystems are not steady state; rather, streams are invariably dynamic, and their conditions vary in space and time because of periodic events such as wildfire and large storms and subsequent floods, hillslope failures, landslides, and debris flows. The signatures of these events are most visible at tributary junctions, which also are sites of high biological diversity (Benda and others 2004).

Since the Plan was implemented, several studies examined the dynamics of aquatic ecosystems in space and time. Reeves and others (1995) described the range of conditions of watershed in the Tyee sandstones of the central Oregon coast in response to wildfire. They found a range of conditions from less productive to more productive. The most complex habitat and biologically diverse fish assemblage was found in a stream that was about 160 to 180 years from the last major wildfire disturbance. Simplified habitat conditions and less diverse fish assemblages were found in streams that were more recently disturbed (80 to 100 years) and that had not been disturbed for a longer period (300+ years). This pattern appears to have resulted from the change in amounts of wood and sediment over time. Immediately after a wildfire, channels are filled with sediments and, as result, much of the wood is buried. The amount of sediment decreases over time because it is eroded and exported from the system faster than it is being delivered to the channel from hillslopes stabilized by forest recovery. Habitat conditions improve as the amount of sediment declines and wood increases either from recruitment or excavation. After extended times, however, sediment declines to amounts that do not support development of pools.

Headwater streams in the same region studied by Reeves and others (1995) exhibited a different pattern of variation in conditions over time (May and Gresswell 2004). Channels that had not been disturbed for several decades were filled with gravel and wood. Recently disturbed channels were devoid of sediment and wood and were scoured to bedrock. Benda and Dunne (1997a, 1997b) and Benda and others (1998) described a similar distribution of in-channel sediment conditions in watersheds over time. Benda and others (2003b) examined the effects of landslides after wildfires on aquatic ecosystems in the Boise River, Idaho. The landslides significantly affected the channel, creating complex channels and delivering large amounts of wood to the channel. As was observed in the Oregon Coast Range (Reeves and others 1995), channel conditions are expected to vary widely over time. See box on next page for further discussion on the variation among watersheds in the response to large disturbance events.

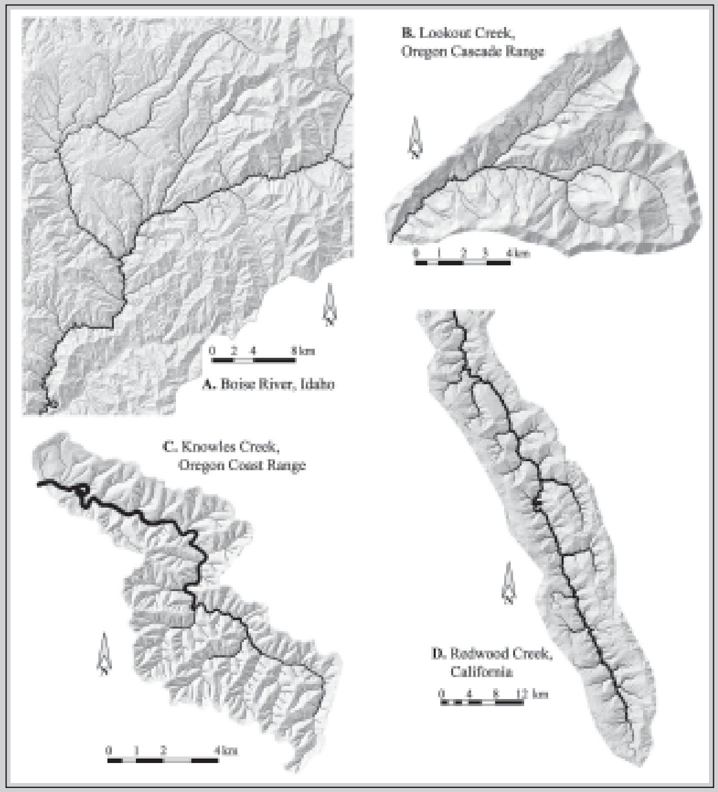
Several factors influenced the responses of these studies. The physical legacy of the disturbances was important; wood in headwater channels accumulated gravel and began the refilling process. Wood and sediment delivered to fish-bearing streams from headwater channels facilitated development of conditions favorable to fish over time. Refugia can be areas that afford protection to individuals during the disturbance event and in the affected area or in nearby areas that are not affected and provide sources of individuals to reestablish populations in affected areas (Roghair and others 2002, Sedell and others 1990). The life history (Dolloff and others 1994) and habitat requirements (Reeves and others 1993, 2002) can also influence the immediate and long-term responses of a population to disturbance events.

Implications—

The dynamic view of aquatic ecosystems and landscapes just described is at odds with the experience and perspectives of some in the research, management, and regulatory agencies and the public. Montgomery and others (2003) questioned the role that dynamics play under natural conditions. They contend that the role of disturbances such as debris flows in old-growth forests is limited. They believe that models of disturbance ecology for salmonids, such as that presented by Reeves and others (1995), need to recognize differences in the disturbance dynamics of old-growth and industrial forests to "provide credible avenues

Variation in Susceptibility to and Response of Watersheds in the Northwest Forest Plan Area to Natural Disturbances

The recognition that dynamic processes, such as periodic large disturbances, have strong impacts on aquatic ecosystems represents a relatively new perspective (for example, Naiman and others 1992, Resh and others 1988). Moderate to large-scale fluctuations in the movement and storage of sediment and wood during these events can create habitats and features that have long-term implications for system productivity (Benda and others 2003b). There is wide variation in the response of aquatic ecosystems to given disturbance events depending on the frequency and magnitude of the disturbance event and a watershed's local topography, channel type (Montgomery and Buffington 1993), shape and configuration of the stream network (Benda and others 2004), and soil and rock type. The four watersheds shown here illustrate some of this variation. The North Fork of the Boise River (A) is outside the Plan area but is representative of parts of the dryer portions of the Plan area. In these steeper systems, periodic disturbances are relatively frequent because of wildfires, but the disturbances have moderate impacts on the channel, and the system is relatively resilient. Postfire sedimentation can lead to large-scale channel changes in small streams and local changes in large channels at tributary confluences (Benda and others 2003a).



Figures from L.E. Benda. 2005. Geomorphologist, Earth Systems Institute, Mount Shasta, CA.

Lookout Creek (B) is on the west side of the Cascade Mountains. It is in an area of hard rock and has a relatively limited stream network. Additionally, the channel gradient is relatively steep. Wildfires and floods, the primary natural disturbances, are relatively infrequent but large. The channel is generally resilient to disturbances, except at some lower gradients spots within the network. The range of conditions observed within the channel is relatively limited.

Knowles Creek (C) is in the soft rock Tyee sandstones of the central Oregon coast, similar to the streams studies by Reeves and others (1995). The primary natural disturbances are infrequent, but large, floods and wildfires. The watershed is characterized by relatively steep tributaries and a lower gradient main channel. The latter results in the deposition of large amounts of wood and sediment in the channel, which experiences a wide range of conditions over time as a result of disturbances events.

Redwood Creek (D) is in northern California. The basin is long and narrow and has a large natural sediment load. The upper portion of the basin is relatively narrow so material moves through it relatively quickly; as a result, inchannel conditions are relatively stable. The lower end is lower gradient and, as a result, is a depositional area. Consequently, there can be a wide variation in habitat conditions over time.

for determining risk associated with land management in steep forested terrain" (Montgomery and others 2003). They believe that "management recommendations based on evolutionary interpretations that are themselves based on a disturbance model primarily applicable to industrial forests may prove misleading" (Montgomery and others 2003).

Clearly, obstacles remain in the path toward a fully implemented ACS that is consistent with the vision articulated in FEMAT (1993) and the ROD (USDA and USDI 1994). Experience has shown that the ACS accommodates a management model that is an alternative to site-specific standards and guidelines. Reeves and others (1995, 1998, 2002) presented an example for the Oregon Coast Range. Another example was for the central Oregon Cascade Mountains (Cissel and others 1998). Progress could be facilitated by attention to several pressing issues.

Focusing policies for and management of aquatic ecosystems at the landscape scale presents challenges to policymakers, managers, and regulators (Reeves and others 2002). A fuller exposition of the HRV would provide a richer understanding of how the conditions of aquatic ecosystems vary through time at all spatial scales and the ecological, social, and economic implications of this variation. Currently, the historical range of the conditions of aquatic ecosystems is assumed to be small and, generally, to be good for habitat. Many managers, regulators, and interested citizens expect aquatic conditions to be relatively constant through time and to be good in all systems at the same time. More realistic expectations would aid both implementing and assessing the ACS.

The interaction of multiple processes operating at multiple spatial and temporal scales is difficult to understand, and even more difficult to incorporate into a coherent management strategy. Understanding the relation among different spatial scales is necessary to successfully assess the effects of management policies and activities on aquatic ecosystems in the future. The challenge is to develop a process that not only looks at current aquatic conditions but also:

- Looks broadly to determine the large context.
- Looks historically to assess past trajectories of the systems and natural history.
- Looks ahead to identify potential threats and expectations.

This perspective would allow for a more integrated response to basic questions such as Where are we, where do we want to go, and how do we get there? Watershed assessment is a logical forum to explore these questions.

The failure to recognize the landscape focus of the ACS has precluded consideration of potential options for different management practices and policies. Some practices and policies for managing aquatic ecosystems under the Plan are in many ways similar to those before the Plan. For example, cumulative effects are still determined at the 6^{th}- to 7^{th}-field watershed scale. Thus, management activities are dispersed among watersheds to avoid potential negative effects (fig. 9-4a). But this approach is not necessarily consistent with the landscape focus of the ACS. A potential alternative option was offered by Reeves and others (1995). They suggested that management activities be concentrated in a given watershed for an extended period (fig. 9-4b), rather than dispersed over wider areas. Grant (1990) modeled both scenarios to determine their effects on the pattern of peak flows and found little difference between the two. Concentrating rather than dispersing activities may also confer benefits to terrestrial organisms that require late-successional forests (Franklin and Formann 1987).

Specifying the spatial scale is important when range of natural variation and cumulative effects are discussed or evaluated. At small scales, the HRV is very large, so, except for the most extreme impacts, no cumulative effects may result from management actions. Most assessments of the effects of human activities are made at relatively small scales. Failure to recognize the relation between space and HRV undoubtedly contributed to the current confusion about the ACS and the scales at which it is applied and how compliance is measured.

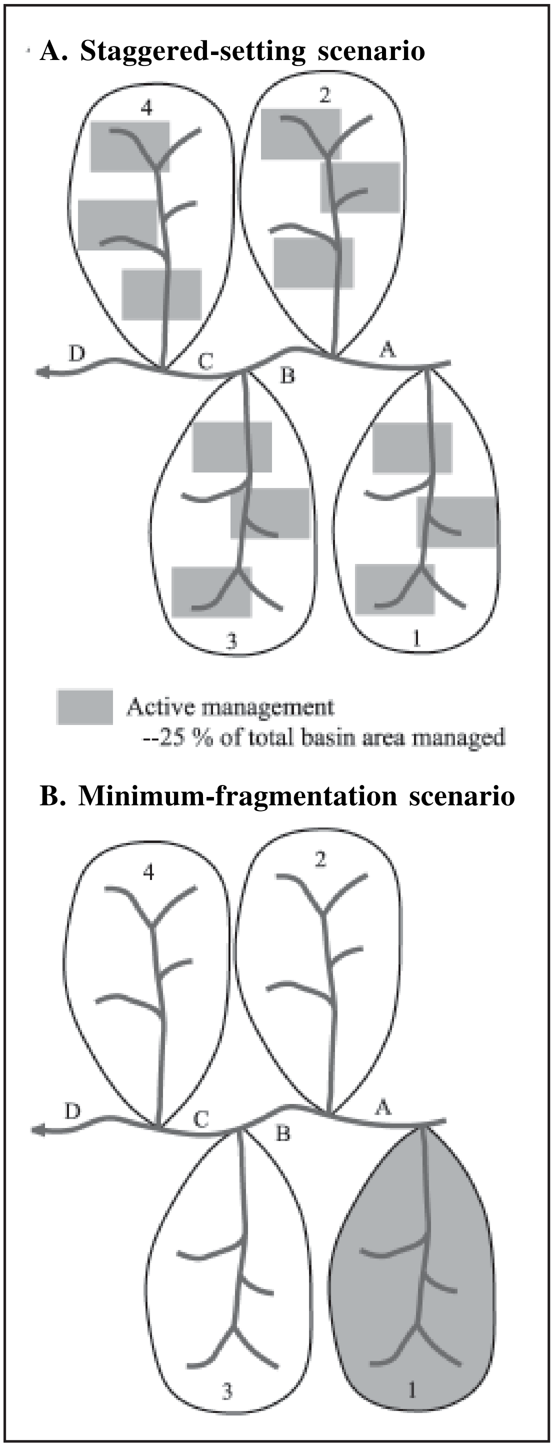


Figure 9-4—Potential approaches to watershed (A) and landscape (B) management. Source: Grant 1990.

The view of aquatic ecosystems as dynamic entities has implications for the network of key watersheds and the potential long-term success of the ACS. First, an underlying assumption about key watersheds was that streams in old-growth forests contained the best habitats for fish. Many of the key watersheds in option 9 of FEMAT (1993) were associated with late-successional reserves. Reeves and others (1995) suggested that streams in mid-successional forests were more productive than those in old-growth forests in the Oregon Coast Range. Whether this pattern is found in other areas is not known at present and could be a future research emphasis. The second implication of treating aquatic ecosystems as dynamic entities deals with the expectations for reserves in dynamic landscapes. Reserves in such a setting cannot be expected to persist for long periods. How future key watersheds will develop and where in the landscape they will occur are key questions for managers, regulators, and researchers to consider.

Riparian Reserves

Ecological functions and distance—
The generalized curves (fig. 9-5) developed in FEMAT (1993) were developed by examining the available scientific literature about key ecological processes in riparian ecosystems. The effects of riparian vegetation decreased with an increasing distance from the streambank (FEMAT 1993). Generally, most ecological processes occurred within 100 feet (about two-thirds the height of a site-potential tree) (fig. 9-5).

An exception was large wood (fig. 9-5a). Large wood provides a crucial ecological function (see Bilby and Bisson 1998, Spence and others 1996) in aquatic ecosystems in the Plan area and is readily acknowledged by land management and regulatory agencies. In developing the generalized curve for wood sources, trees were assumed to reach a stream from a slope distance equal to the height of the tree (FEMAT 1993). Implicit in this assumption, but unstated by FEMAT (1993), was that trees in the riparian zone farthest from the channel would not immediately be

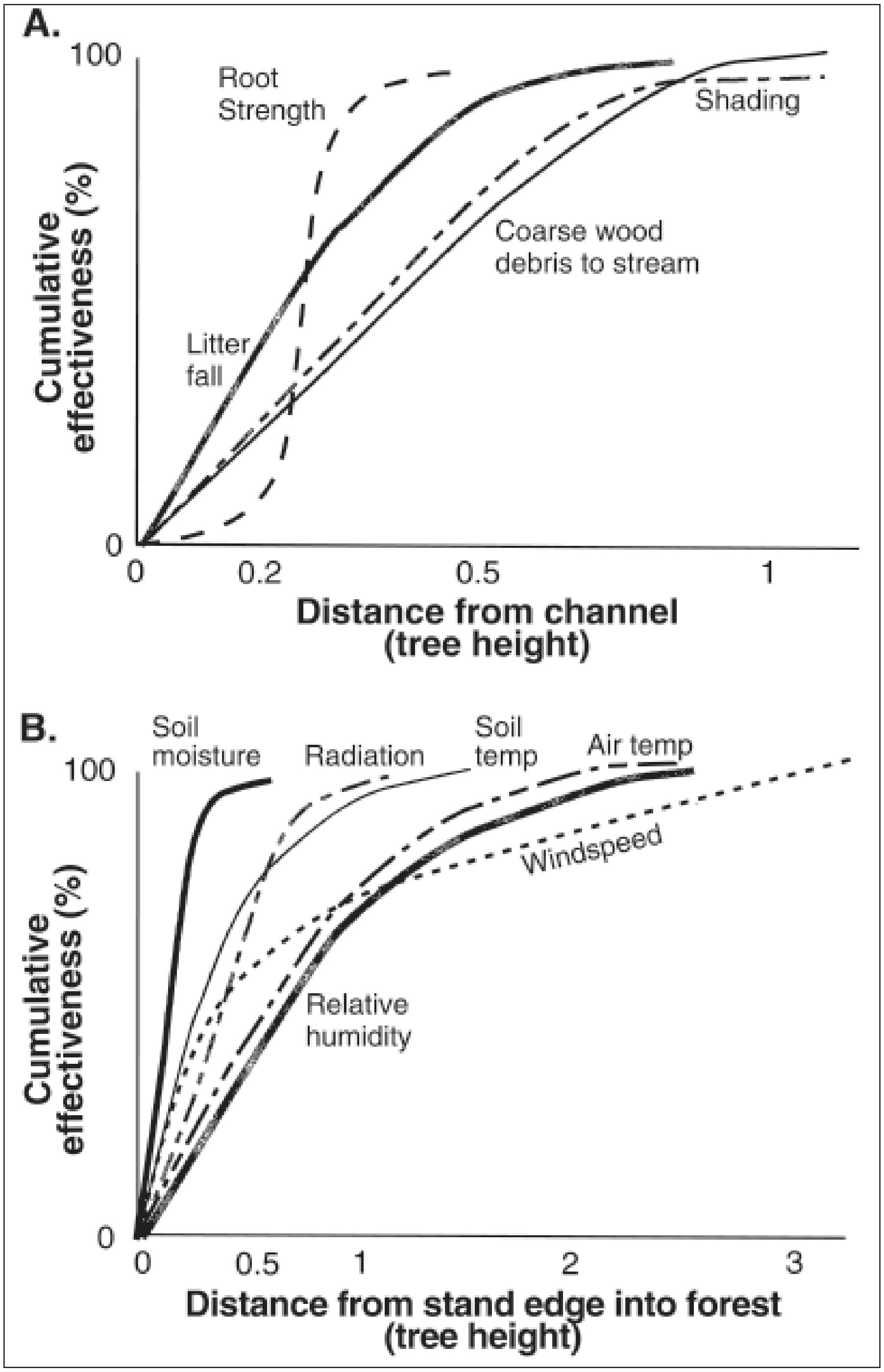


Figure 9-5—Generalized ecological functions in riparian zones as a distance from the stream. Source: FEMAT 1993.

in the current stream channel. These trees could either be recruited over time to the channel or, with wide valley floors, the channel would migrate over time and such pieces could then be in the channel. Bilby and Bisson (1998) noted that the latter process may be an important source of wood for streams in some areas.

Recognition of the role and importance of down wood in riparian areas has increased since the ACS was implemented. Down wood, particularly larger pieces, provides required high-moisture microhabitats for many riparian-associated amphibians (Pilliod and others 2003). It also provides habitat for several species of birds and small mammals found in riparian areas (Kelsey and West 1998). And down wood may collect and impede the movement of finer sediment into streams, preventing fine sediment from reaching streams where it can affect habitat conditions and biota (see references in McIver and Starr 2001, Wondzell and King 2003). This effect may be particularly important in areas where chronic overland erosional processes dominate, which are very rare in the Plan area except after intense fire or severe management disturbance. Trees in the riparian area farthest from the channel are sources of this down wood.

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Carcasses of salmon and trout provide nutrients for riparian vegetation and a number of aquatic and terrestrial organisms.

Microclimate conditions in riparian areas was another ecological function in addition to wood sources that occurred beyond 100 feet (a distance of about two-thirds of the height of a site potential tree) (fig. 9-5b). Based on the work of Chen (1991), the developers of the ACS (FEMAT 1993) argued wider buffers may be needed to maintain interior microclimatic conditions. Subsequent work by Brosofske and others (1997) supported this contention. Maintaining favorable microhabitat conditions in riparian areas is also important for wildlife species (Kelsey and West 1998).

Headwater streams—

The riparian reserve was one of the cornerstones of the ACS. The riparian reserve network included fish-bearing streams, which had been the focus of management of aquatic ecosystems before FEMAT, as well as small, fishless headwater streams. The latter generally make up 70 percent or more of the stream network (Gomi and others 2002). Before the ACS, these streams were not widely recognized as part of the aquatic ecosystem, but knowledge about and recognition of the ecological importance of headwater streams has increased since then. They are sources of sediment (Benda and Dunne 1997a, 1997b; Zimmerman and Church 2001) and wood (Reeves and others 2003) for fish-bearing streams. They provide habitat for several species of native amphibians (Kelsey and West 1998) and macroinvertebrates (Meyer and Wallace 2001), including recently discovered species (Dieterich and Anderson 2000), and may be important sources of food for fish (Wipfli and Gregovich 2002). Small streams are also storage and processing sites of nutrients and organic matter, important components of the energy base for organisms used by fish for food (Kiffney and others 2000, Wallace and others 1995, Webster and others 1999, Wipfli and Gregovich 2002).

Headwater streams are among the most dynamic portions of the aquatic ecosystems (Naiman and others 1992). Tributary junctions between headwater streams and larger channels are important nodes for regulating material flows in a watershed (Benda and others 2004, Gomi and others 2002) and are the locations where site-scale effects from management activities are often observed. These locations have unique hydrologic, geomorphic, and biological attributes. The movement of sediment, wood, and other materials through these locations results in sites of high biodiversity (Johnson and others 1995, Minshall and others 1985). Habitat in these sites may also range from simple to complex, depending on time from the disturbance (such as landslides and debris flows) and the types and amount of materials delivered to the channel.

Large wood is an important element of stream and river ecosystems. It forms and influences the size and frequency of habitat units for fish and other organisms that depend on aquatic and riparian habitats (Bilby and Bisson 1998, Bilby and Ward 1989, Wallace and others 1995). The size of pieces and amount of wood in the channel also influences the abundance, biomass, and movement of fish (Fausch and Northcote 1992, Harvey and Nakamoto 1998, Harvey and others 1999, Murphy and others 1985, Roni and Quinn 2001). Wood enters streams via chronic and episodic processes (Bisson and others 1987). Chronic processes, such as tree mortality and bank undercutting (Bilby and Bisson 1998, Grette 1985, Murphy and Koski 1989), generally introduce single pieces or relatively small numbers of trees at frequent intervals. Episodic processes usually add large amounts of wood to streams in big but infrequent events, such as windthrow (Harmon and others 1986), wildfire (Agee 1993), severe floods, and landslides and debris flows (Keller and Swanson 1979, May 2002, Reeves and others 2003).

Examinations of wood sources in streams (such as McDade and others 1990, Murphy and Koski 1989, Robison and Beschta 1990) have focused until recently on chronic input from the immediately adjacent riparian zone. Such studies concluded that most of the wood found in streams was derived from within a distance of about 100 feet. Riparian management in forest plans developed before the Plan was based primarily on these cited studies and assumed that most of the wood found in streams came from within 100 feet of the stream. The studies on which this assumption was made, however, either did not consider episodic sources of wood (such as Van Sickle and Gregory 1990) or did not sample study reaches influenced by upslope sources (such as McDade and others 1990). The assumption that all wood came from within 100 feet of the channel based in the cited studies is incorrect, and the potential effectiveness of plans and policies based on it are questionable.

In steep terrain, which is found on much of the Plan area, landslides and debris flows are potentially important mechanisms for delivering sediment and wood from hillslopes and small headwater channels to valley-bottom streams. Reeves and others (2003) found that an estimated 65 percent of the number of pieces and 46 percent of the total volume of wood in a pristine watershed in coastal Oregon came from outside the riparian zone immediately adjacent to the fish-bearing stream. More than 80 percent of the total number of pieces of wood in a western Washington stream (Benda and others 2003b) and a northern California stream (Benda and others 2002) were from upslope sources. Other studies, such as May (2002) and Benda and others (2003a), found large amounts of wood from upslope sources in streams in the Oregon Coast Range and Idaho, respectively.

Pieces of large wood delivered from upslope areas are generally smaller than those originating from the riparian zones along fish-bearing streams. Reeves and others (2003) found that the mean volume of a piece of large wood from upslope areas was one-third the mean size of pieces from stream-adjacent riparian areas in a coastal Oregon stream. Difference in mean size is likely attributable to fire history and other stand-resetting events. Hillslopes are more susceptible to fire and burn more frequently than streamside riparian zones (Agee 1993). Thus, trees in the streamside riparian zone may be disturbed less frequently and achieve larger sizes than upslope trees.

Geomorphic features of a watershed influence the potential contribution of upslope wood sources. Steeper, more highly dissected watersheds will likely have a greater proportion of wood coming from upslope sources than will watersheds with lower gradients. Murphy and Koski (1989) and Martin and Benda (2001) found that upslope sources of wood composed a relatively small proportion of the total wood in streams that they examined in Alaska. The watershed studied by Martin and Benda (2001) had a wide valley floor, so wood was deposited along valley floors away from the main channel. In contrast, Benda and others (2003a) found that wood delivered in landslides after wildfires was deposited in wide valley reaches in the Boise River, Idaho. In a central Oregon coast stream, Reeves and others (2003) found that the amount of upslope-derived wood was greatest in reaches with narrow valley floors.

Even in watersheds where the potential contribution from upslope sources of wood is high, the ability of individual upslope sources to contribute wood to fish-bearing streams can differ widely. Benda and Cundy (1990) identified the features of first-and second-order channels with the greatest potential to deliver sediment and wood to fish-bearing streams in the central Oregon coast. The primary features were gradients of 8 to 10 percent with tributary junction angles <45°. These features can be identified from Digital Elevation Models (DEMs) and topographic maps. Benda and others (N.d.) have developed a process that uses information from DEMs to develop basin-specific information for stratifying landscapes for varying intensity of resource management, identifying ecologically significant terrain for conservation, and prioritizing watershed and instream restoration and monitoring activities.

The presence of large wood from headwater streams influences the behavior of landslides and debris flows and the response of the channel to such events. Large wood in debris flows and landslides influences the runout length of these events (Lancaster and others 2003). Debris flows without wood move faster and longer distances than those with wood, and they are less likely to stop high in the stream network and to reach fish-bearing channels. A debris flow without wood is likely to be primarily a concentrated slurry of sediments of varying sizes that can move at relatively high speeds over long distances scouring substrate and wood from the affected channels. These types of flows are more likely to negatively affect fish-bearing channels rather than have potential favorable effects that result from the presence of wood. They can further delay or impede the development of favorable conditions for fish and other aquatic organisms.

Over time, headwater depressions and channels are filled with material from the surrounding hillslopes, including large wood that falls into these channels, forming obstructions behind which sediments accumulate (Benda and Cundy 1990, May and Gresswell 2004). These areas are evacuated following a landslide or debris flow. This cycle of filling and emptying results in a punctuated movement of sediment and wood to larger, fish-bearing streams (Benda and others 1998), which is—at least, in part—responsible for the long-term productivity of many aquatic ecosystems (Benda and others 2003a, Hogan and others 1998, Reeves and others 1995). The absence of wood to replenish the refilling process may result in a chronic movement of sediment to larger channels, which could lead to those channels developing different characteristics than those that occurred before forest management. Such conditions could be outside the range of watershed conditions to which native biota are adapted (Beschta and others 2004).

Fire and riparian and aquatic ecosystems—
The issue of fire and aquatic ecosystems was given little consideration by the Aquatic Conservation Plan's developers (FEMAT 1993), primarily because the potential threat of fire to aquatic ecosystems was not widely recognized at that time. Since then, numerous studies have examined the effect of fire on upland ecosystems, but relatively few examined aquatic and riparian ecosystems. Those studies that considered riparian areas generally focused on perennial streams, and the specific results differ with geographic location. In general, the frequency and

magnitude (following the definitions of Agee 1993) of fires in riparian areas is less than in adjacent upslope areas. Differences between fire effects on riparian and upland areas are less in regions with more frequent and less severe fires compared to locations where the fire return interval is larger and the fires are more severe. Fire in riparian areas along intermittent streams has not been studied, most likely because the inclusion of these areas as part of the riparian systems is only recently beginning to be recognized. Assuming that the effects of fire on the riparian zones of ephemeral and intermittent streams are similar to fire effects on upland plant communities is probably safe; however, I acknowledge that much additional research is needed.

Wildfire can profoundly affect watersheds and streams and associated aquatic organisms. The immediate effects of severe fires that burn through riparian areas and across small streams may include high mortality or emigration of fishes and other organisms caused by direct heating and changes in water chemistry (Minshall and others 1997, Rieman and Clayton 1997, Spencer and others 2003). Subsequent effects associated with the loss of vegetation and infiltration capacity of soils may include increased erosion, changes in the timing and amount of runoff, elevated stream temperatures and changes in the structure of stream channels (Benda and others 2003a, Wondzell and King 2003). The nature of these changes depends on the extent, continuity, and severity of the fire, and on lithology, landform, and local climate (Luce, in press; Rieman and Clayton 1997; Swanson and others 1988). A severe fire burning through dense fuels can produce extensive areas of hydrophobic soils (DeBano and others 1998). If a large storm follows in steep, highly dissected terrain, the result can be massive erosion and debris or hyper-concentrated flows that completely reorganize entire segments of mountain streams and deposit large volumes of sediment in lower gradient reaches (Benda and others 2003a).

Whether fire is viewed as ecologically catastrophic, however, is a matter of context and scale. Following the Boise fire in central Idaho, most fish populations rebounded quickly, in part through dispersal from unburned stream refugia (Rieman and Clayton 1997). Roughly 10 years after the disturbance, little evidence remains to suggest that the distribution and abundance of fishes in these streams are fundamentally different from similar-sized unburned streams. Beneficial effects of fire, such as increased primary productivity and invertebrate abundances, may offer mechanisms for individual fish to cope with potentially stressful conditions (such as high temperatures) in disturbed streams. Further, on timescales of decades to millennia, large disturbances have been common in these landscapes. Fishes and other species probably evolved mechanisms such as dispersal and plasticity in life history that allow them to recover (Dunham and others 2003, Reeves and others 1995).

Additionally, physical complexity in a stream may increase after a wildfire. Recent work has shown that fire and subsequent hydrologic events can contribute wood and coarse sediment necessary to create and maintain productive instream habitats (Bisson and others 2003, Reeves and others 1995). Benda and others (2003a), for example, have shown how mass erosion and deposition at tributary junctions can produce important heterogeneity in channel structure. Natural disturbances interacting with complex terrain has been linked to a changing mosaic of habitat conditions in both terrestrial and aquatic systems (Bisson and others 2003, Miller and others 2003, Reeves and others 1995). This variation of conditions in space and time may be the key to evolving and maintaining biological diversity and, ultimately, the resilience and productivity of many aquatic populations and communities (Bisson and others 2003, Dunham and others 2003, Poff and Ward 1990).

Land managers may view salvage logging after wildfire as a potential restoration technique by which they can respond to the perceived adverse effects of fire (McIver and Starr 2001). Research on the effects of postfire salvage logging on terrestrial organisms has shown mixed results; some organisms showed no effect, others increased (such as, Blake 1982, Haim and Izhaki 1994), and others declined

(Saab and Dudley 1998). Studies on the potential effects of fire and postfire logging of riparian systems and associated biota are lacking, however. Reeves and others (2006) argue that salvage logging in riparian zones may, among other things, reduce the amount and size of wood delivered to stream channels. This reduction may have immediate and long-term ecological consequences for trophic inputs and physical habitats of streams. Activities associated with salvage logging, including building new roads or opening old ones, may further exacerbate the effects of salvage logging by increasing erosion and fragmentation of the stream network. Although, in some circumstances, concerns about human safety justify salvage logging in a riparian zone, there is presently a paucity of evidence of scientific support for salvage logging in riparian zones (Reeves and others 2006). This certainly is an area worthy of future research.

"Cultural shifts" within the land management agencies—

Implementation of the Plan and ACS bought major changes to the way the affected agencies viewed and managed aquatic resources and watersheds. It is difficult to accurately describe or to quantify these changes, but conversations with agency personnel reveal that the vast majority believe that these changes were the most important effect of the Plan and ACS. The ACS replaced local plans that contained a variety of management directions and objectives with a common framework for managing aquatic and riparian resources on public lands. Additionally, it required a more comprehensive approach to the management of aquatic and riparian resources and much more interaction among disciplines that previously had little interaction. Table 9-3 summarizes these changes in agency culture, analysis, and analytical basis of management. In the view of many of the people responsible for the implementation of the ACS, these changes clearly are the primary successes of the Plan.

In a survey authorized by the Forest Plan Revision Board of Directors of FS Pacific Northwest Region (Region 6), personnel involved with the implementation of the ACS (forest and district fish biologists, hydrologists, and wildlife biologists) believed that ACS was appropriate and that it has led to improved and proactive management of aquatic resources (Heller and others 2004). The respondents also believed that there was a need to develop a single unified regional ACS, and this was accepted by the Board of Directors. A single framework is currently being developed for FS Region 6 with the Plan ACS as its cornerstone.

Summary and Considerations

Producing a quantitative assessment of the ACS of the Plan continues to be challenged by issues of data availability and quality. First, the accuracy and quality of data on some activities is questionable. For example, Baker and others (in press) report in their summary that the FS and BLM reported decommissioning 295 miles of road. When they examined 89 watershed assessments done between 1999 and 2003, they found that road mileage in those watersheds was reduced by 1,179 miles. Data on important indicators of effectiveness, such as miles of streams with water quality problems (that is 303d-listed streams) on federally managed lands and volume of timber harvested in riparian reserves, are not available. Watersheds degraded by management activities before the Plan was implemented were expected to take several years or decades to recover (FEMAT 1993). Thus, it is not too late to assemble credible data on activities and actions done under the auspices of the ACS. Field units are improving watershed conditions by removing and improving roads, in-channel restoration projects, improving riparian areas, and so forth, in addition to providing some timber volume from the riparian reserve network. The land management agencies could consider requiring field units to report uniformly on selected key activities and have the data assembled and accessible in a central location. The availability of such data would allow for at least a more defensible qualitative assessment of the effectiveness of the ACS.

Table 9-3—Changes in paradigms for managing aquatic and riparian resources that occurred as result of the implementation of the Plan and Aquatic Conservation Strategy

Old	New
Management activities can occur unless unacceptable adverse impacts can be shown likely to occur.	Management activities should contribute to, or not retard, attainment of ACS objectives.
There is a variety of individual approaches for the protection and restoration of aquatic and riparian-dependent resources. These are often different between administrative units for no apparent reason.	There is a consistent strategic approach for the protection restoration of aquatic and riparian-dependent resources across the entire Plan area.
Focus is on the condition of individual streams or stream segments or sites. Attention is focused primarily on public land.	Management focus is on process and function of whole watersheds. Special efforts are made to consider and coordinate activities on all ownerships.
Effectiveness monitoring is highly variable between administrative units. Protocols are inconsistent and preclude summarization and analysis across the Plan area.	There is a formal program, with consistent protocols, to monitor effectiveness of the strategy across the Plan area. Data can be summarized and analyzed for the Plan area.
Federal agencies generally work independently. Coordination is often infrequent and driven by "problems." Efforts to involve all stakeholders occur but are not the norm.	The emphasis is to coordinate the activities of federal agencies in the implementation and evaluation of the Plan. Special efforts are made to include all stakeholders.
Proposed actions came from "target" generally unrelated to ecosystem characteristics. Analysis is generally single disciplinary, single scale, and noncollaborative.	There is a multiscale analysis of ecosystem form and function prior to formulating proposed actions.

Source: Heller 2002.

The ACS met its expectation that watershed condition would begin to improve in the first decade of the Plan. The conditions of watersheds in the Plan appear to have improved slightly since the Plan was implemented. The proportion of watersheds whose conditions improved was significantly greater than those that declined. A primary reason for this improvement was an increase in the number of large trees in riparian areas and a decrease in the extent of clearcut harvesting in riparian zones. This general trend of improvement should be expected to continue, and may actually accelerate in the future, if the ACS is implemented in its current form. It is highly likely that these trends would have been the reverse under many of the forest plans that were in place before the ACS.

Science information developed since the Plan was implemented supports the framework and components of the ACS, particularly for the ecological importance of smaller, headwater streams. Also, a growing body of science about the dynamics of aquatic and riparian ecosystems could provide a foundation for developing new management approaches and policies. Scientifically based tools for aiding watershed analysis are also available and could be considered for use by the various agencies.

One of the main topics that could be examined and considered in more detail is that of the relation between spatial scales that are considered by the Plan and the ACS. The Plan and ACS changed the focus of the land management agencies from small spatial scales (i.e., watersheds) to larger scales (that is, landscapes). It appears that the implications of doing this have not been fully recognized or appreciated by the land management or regulatory agencies, and it has created confusion with the public and policymakers. This has precluded the consideration of new options and approaches to management. A rigorous examination of this issue would certainly be worthwhile.

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Chapter 10: Adaptive Management and Regional Monitoring

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Introduction

We have cast a broad net in evaluating adaptive management in the Northwest Forest Plan's (the Plan) first decade. We include the experiences with adaptive management areas, adaptive management outside of those areas, the regional interagency monitoring program, and some aspects of public-participation policy. Because the Plan tried an ambitious form of adaptive management, meeting all of its expectations would be an unparalleled achievement—this approach at this scale was never tried before the Plan. Adaptive management was seen as a cornerstone of the Plan, in response to clearly articulated uncertainties about how the chosen approach would play out. About 1.5 million acres (6 percent of the Plan area) was set aside into a land-use designation called adaptive management areas (see fig. 1-1), which were given a special mandate for learning. Regional monitoring grew out of directives specific to owls from the Dwyer injunction and subsequent rulings into specific requirements in the Plan (USDA and USDI 1994). Although adaptive management and monitoring were implemented largely independently, we consider them together now because they are both central to the general process of adaptive management, also mandated by the Plan. We also evaluate how the concepts, presentation, and, perhaps, the goals of adaptive management continued to evolve during the Plan's first decade.

The Plan was designed to manage environmental risk by applying the precautionary principle, and to actively seek to reduce uncertainty with adaptive management and monitoring. The designers and implementers of the Plan recognized that uncertainty and risk are inherent in natural resource management and public policy (chapter 3). In social and ecological systems as large and complex as the Pacific Northwest, myriad interacting factors ensure that people's best-made plans or intentions are disrupted by unexpected human and natural events and, in retrospect, many rational predictions look more like guesses. Uncertainty arises in two major forms: natural variability of processes and lack of knowledge. With variability, the process involved is understood, but the realized values can only be predicted within a range (for example, population growth rates or timber prices). In contrast, lack of knowledge includes both what is thought to be true (or false) but is not, and what is true but not thought about (such as unknown natural processes). When uncertainty intersects with objects or services of value, then loss can happen; the probability of lost value is known as risk.

The precautionary principle, as applied when the Plan was implemented, dictated that activities with risks of environmental degradation, such as harvest in riparian reserves or salvage, were halted or could proceed only if net ecological benefits of the action could be demonstrated. Thus, the Plan created a burden of proof that favored passive protective measures over active management. The Plan, as perhaps is not widely appreciated, also recognized the limits to this approach. Recognizing the benefits of active management in some instances, and the uncertainty in both action and inaction, Plan designers looked to adaptive management as a way to address uncertainty. The adaptive management concepts of Holling (1978), Walters (1986), and Lee (1993) were added as the primary mechanism for using management activities as experiments, and thus encouraging managers to learn by doing. Through time, such learning would reduce uncertainty and be incorporated into Plan direction.

Conflict can arise when the precautionary principle is invoked without formal risk assessment. With a consensus that possible negative outcomes are large relative to possible positive outcomes, little debate would happen regardless of different opinions or exact probabilities. For example, if a thunderstorm is approaching, few would question a decision to move children from a playground to

The Precautionary Principle

The precautionary principle has become increasingly prominent in environmental management. Simply stated, it rejects inaction as a response to uncertainty. A widely quoted definition from the 1992 Rio Declaration,* states:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The basic idea behind the precautionary principle is common to human experience; where a possible but uncertain threat to life or property exists, precaution calls for reasonable effort at avoidance. Sometimes avoidance calls for active measures (such as security screening in public buildings) and, at other times, stopping activities that might otherwise take place (such as prohibiting use of cell phones on airplanes).

Note that the precautionary principle does not advocate avoiding all actions with possible negative consequences, nor does it suggest avoiding environmental degradation at all cost. As defined in the Rio Declaration, the precautionary principle is fully consistent with formal methods of risk assessment and risk management that have been developed as models of rational behavior. In quantitative risk assessments, a range of plausible outcomes is identified and probabilities are associated with each outcome. Expected loss, or risk, is calculated by summing the probability of each outcome multiplied by its associated loss or gain in value. Decisions that result in high expected loss are viewed as undesirable. The precautionary principle logically follows when negative outcomes are highly probable, or when the magnitude of the potential loss is very high relative to possible gains, regardless of probabilities. In either case, attempting to reduce the chance of loss is prudent.

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* Drafted at the 1992 United Nations Conference on Environment and Development, also known as Agenda 21.

a protected area. But many environmental decisions are not so obvious. Often the probabilities are not well understood, and assigning value to the range of possible outcomes is highly subjective. In disagreements among values, invoking the precautionary principle invariably favors one set of values over another. Similar conflicts can arise if different groups share the same values, but differ in assessing probabilities because of competing worldviews or, perhaps, lack of trust. Formal risk assessment methods share the same shortcomings, but they have the advantage of explicitly revealing people's value judgments and probabilities.

Because the Plan language about adaptive management was somewhat vague and lacked performance standards, our assessment of intent is unavoidably subjective. Clearly, expectations were suggested in the Plan, and we use them where appropriate. We mainly use standards for an active form of adaptive management as described by Stankey and others (2003):

- Applying elements of the scientific method (specifying hypotheses, highlighting uncertainties, and structuring actions to expose hypotheses to field tests).
- Collecting, processing, and evaluating results.
- Adjusting subsequent actions in light of those results.

Evidence of Changed Direction

Evidence that these expectations were or were not met comes from the status and trends reports and various internal and external reviews, including an agency-funded review (Stankey and others 2003). We later place the Plan experience in the broader context of how well adaptive management has been applied in other places. Because regional interagency monitoring is such an integral part of adaptive management, we look in detail at the regional monitoring program and its dual role of measuring progress and advancing learning.

The primary goal of adaptive management under the Plan was to gain improved understanding to influence Plan changes through time. Clearly, the need for purposeful, systematic learning inside and outside adaptive management areas and in the monitoring program was envisioned. Standards for determining when something has been learned were not developed, however. For example, how much time is needed to produce evidence of sufficient weight to alter the Plan was not discussed, nor does this question have a simple answer. How long depends on the nature of the issue, the inherent rates and dynamics of the processes, and the pace of learning. Much time and effort are needed to learn about complex forests, and perhaps 10 years is insufficient to form many concrete conclusions. Although some uncertainties might be resolved enough to allow quick changes in direction, others could require many decades. Another ambiguity was whether adaptive management was intended to evaluate the Plan approaches simply by monitoring them or to contrast them to alternative strategies, such as disturbance-ecology-based approaches, on the adaptive management areas.

Evidence of a well-coordinated, systematic approach to learning contributing directly to Plan changes is, so far, limited. Stankey and others (2003) interviewed adaptive management area participants who found the new approaches innovative, but candidly recognized the many barriers (internal and external, operational and systemic). An agency committee review[1] found that managers in charge of adaptive management areas came to the same conclusion. They also reported that most studies were funded by the Pacific Northwest Research Station (about 30 studies: 4 that directly tested standards and guidelines and 7 that were in adaptive management areas). These areas were valuable in many ways, but they did not become a learning institution as envisioned by many of the people who proposed the idea.

Regional monitoring and various change mechanisms integral to the Plan do offer evidence of institutionalized learning and adapting. Local successes notwithstanding, evidence of a well-coordinated, systematic approach to adaptive management, including both adaptive management areas and monitoring, are harder to find.

Monitoring was well institutionalized—with multiple agencies working together—to measure Plan success and to provide new knowledge at a regional scale as a basis for decisions. Clearly, new knowledge was produced, and efforts (including this report) are underway to consider whether changes are needed. By itself, regional monitoring is a very passive form of adaptive management that does not compare alternative approaches and is slower than more active forms of adaptive management (Bormann and others 1999). Evidence that a broad systematic approach was implemented in the Plan is also weak. For example, few links were made between regional monitoring and local monitoring or other adaptive management activities.

Several deliberate mechanisms of change in the Plan were successfully implemented. Required monitoring for marbled murrelets (see app. for species names) in matrix lands led to half-mile-radius, late-successional reserves being created when murrelets were found. In response, the Siuslaw National Forest abandoned matrix management partly because they had previously found murrelets in

[1] Intergovernmental Advisory Committee, adaptive management area subcommittee report, March 10, 2004. http://www.reo.gov/library/iac/letters/1910iac3.htm.

about 90 percent of their surveys.[2] The Survey and Manage program was designed to deliberately change survey schedules, individual species categories, and mitigation requirements in response to new information; such changes were made (chapter 8). The decision in 2004 (USDA and USDI 2004) to change from Survey and Manage to a sensitive species program was based on several factors, including cost. This change was viewed by some as passive adaptive management—a new approach was tried, evaluated, and then changed (whether the program was evaluated long enough is still debated). In contrast to changes induced by murrelet and other species surveys, evidence of adjustments in riparian buffers was uncommon (chapter 9).

The decision to thin plantations in late-successional reserves also provides some evidence that an adaptive management process was used. Various stand and landscape research and management studies and experiments—some sponsored by adaptive management areas of the Plan—presented initial evidence that thinning could speed developing late-successional characteristics in plantations in the late-successional reserves (chapter 6). These thinnings were not considered a major source of timber to meet timber production objectives in the Plan, and initially they were not included in the probable sale quantity. In the later years of the Plan's first decade, however, thinnings in late-successional reserves became a major source of timber, benefiting the economy of some local communities (Charnley and others 2006), as well as appearing to move stands toward late-successional conditions. Other changes as the Plan was implemented were precipitated by courts, civil disobedience, or threats thereof, and some were precipitated to avoid contested projects. These types of unstructured reactions to immediate stimuli, appropriate or otherwise, are not widely viewed as adaptive management (Bormann and others 1999, Gunderson 1999a, Walters 1997).

Bruce G. Marcot

Variable-density thinning of an older plantation in a late-successional reserve on Olympic National Forest, Washington. The goals of such thinning are to grow larger diameter trees faster and to create more spatial variability, thereby promoting some characteristics of old-growth forests.

Reflections on Adaptive Management

Any interpretation of adaptive management needs to consider ongoing processes that are producing understanding yet to be adopted (where the adaptive management loop is yet to close). Perhaps the most promising activity is the monitoring program and its 10-year interpretive report, to which this synthesis belongs. Here, we discuss problems and successes in the context of experiences with adaptive management outside of the Plan.

One difficulty in implementing and evaluating adaptive management is ambiguity in its definition. At one end of the spectrum are those who view any reaction to new stimuli as adaptive management. At the opposite end are those who invoke a more rigorous experimental framework characteristic of scientific research. Problems in the Plan seem to have started when no single definition of adaptive management was established. The Plan's most commonly implemented expression of adaptive management appears to be a very passive form, where a single approach was chosen (for example, on the reserves, with the preserve-and-protect tenets

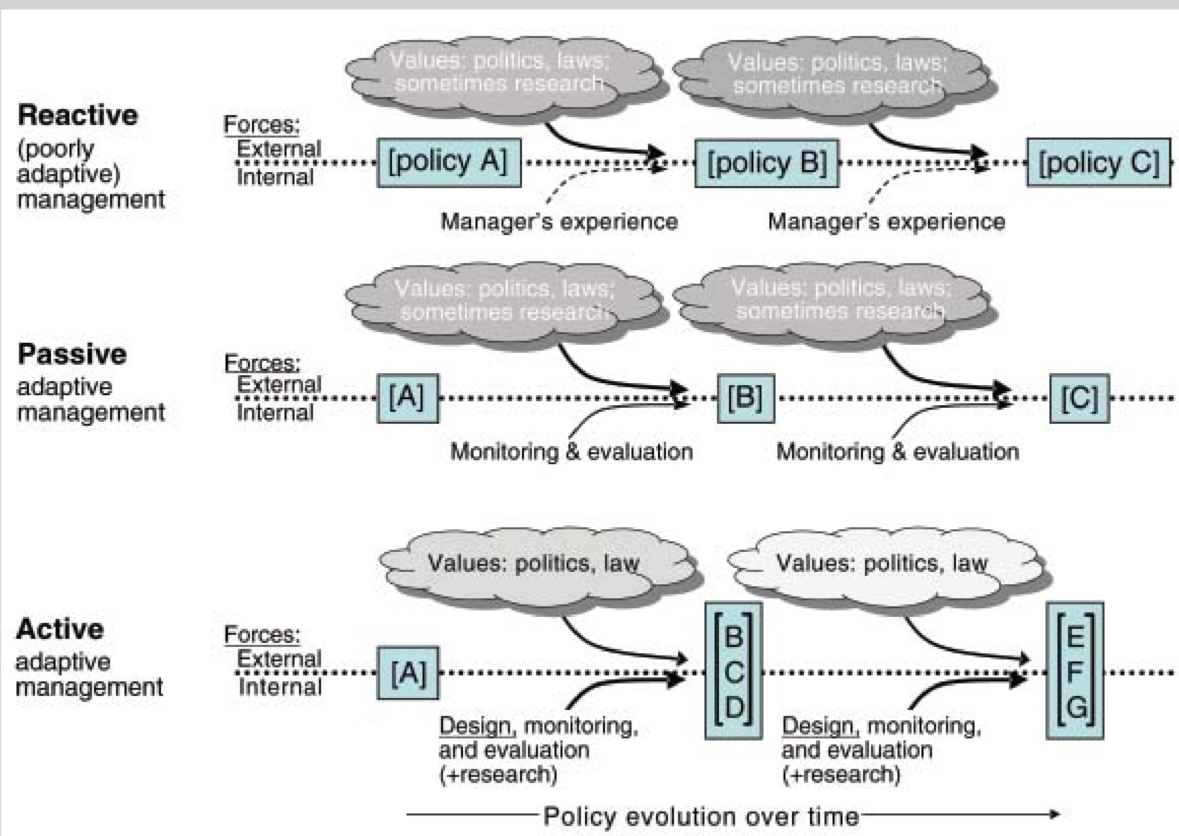
[2] Linares, Jose. 2005. Personal communication, Forest Supervisor, Siuslaw National Forest, 4077 Research Way, Corvallis, OR 97333.

Forms of Adaptive Management

The literature describes three main forms of adaptive management: reactive, passive, and active (figure below). The forms differ in the degree that external factors (such as legislators, courts, and civil disobedience) drive policy evolution more than learning activities internal to the management system, and in how fast policies can evolve given the lengthy evaluation period needed.

- **Reactive management** is not thought to be very adaptive when policies change A to B to C without much influence from what was learned on the ground.
- **Passive adaptive management** adds a specific monitoring and evaluation step to increase the influence of internal knowledge, potentially improving the subsequent policy but perhaps with little effect on the rate of policy evolution.
- **Active adaptive management** adds a design step, seeking to speed policy evolution and make research more of an internal force. Designed "management experiments" speed learning by trying a set of policies simultaneously within scientifically defensible experimental designs (usually subject to rigorous peer review).

Learning is a function of the strength of monitored comparisons; comparing multiple policies simultaneously with replication is far more powerful than trying one at a time. Active adaptive management should not be confused with research—although management experiments use an experimental design, they are developed, implemented, and monitored by managers, with only consultative help from researchers.



of conventional conservation biology), with regional monitoring as the primary feedback and learning mechanism. Most management experiments on adaptive management areas closely resembled traditional research experiments, with tightly constrained treatments on uniform small areas. With a few exceptions, published concepts of active adaptive management (including the interagency implementation report, Bormann and others 1994) were not widely adopted (Pipkin 1998, Salwasser 2004, Stankey and others 2003).

Implementing elements of a broader adaptive management strategy in the Plan area was piecemeal. Multiple interagency implementation teams, with both scientists and managers, were convened after the record of decision, and released in five separate reports (adaptive management areas, adaptive management process [Bormann and others 1994], monitoring, information technology, and planning). Not surprisingly, implementation that followed was compartmentalized (for example, adaptive management areas in provinces, monitoring in the interagency monitoring program). Except for some of their local field personnel, regulatory agencies did not participate in designing learning activities, and many people concluded that their interpretation of adaptive management did not include activities that deviated from the standards and guidelines (Stankey and Shindler 1997, Stankey and others 2003). An initial decision to allow adaptive management to develop without regional oversight was supported by scientists who argued against creating a cookbook for adaptive management (Bormann and others 1994). The lack of direction, coordination, and motivational support from either regional or local decisionmakers, in retrospect, appeared to hinder adaptive management efforts. The perceived lack of progress slowed research and then management funding in adaptive management areas after 1998.

These results are fully consistent with experience in other places, where successful implementing of adaptive management remains rare (Walters 1997). Many of the obstacles that were observed with the Plan are shared by other efforts. Four main obstacles hindered the Plan.

Bernard Bormann

Looking across the heavily managed, structurally diverse landscape of Five Rivers (Siuslaw National Forest), where a landscape-scale, adaptive-management experiment is underway in an area first harvested in 1952.

First, perceived or real latitude to try different approaches on adaptive management areas was limited. Many of the Forest Ecosystem Management Assessment Team (FEMAT) scientists thought that the areas would have wide latitude to test approaches that substantially differed from Plan approaches applied in the late-successional and riparian reserves. This need for experiments was clearly recognized as a way to respond to the large uncertainties in the Plan directions. The rules for adaptive management areas changed as the Plan was written, and most of the latitude was eliminated—for example, riparian reserve standards and guidelines were applied to all and late-successional standards and guidelines to some of the adaptive management areas, and both took precedence over adaptive management standards and guidelines. After much debate, the Regional Ecosystem Office sent a letter clarifying the possibilities and needs for modifying standards and guidelines in the adaptive management areas (REO 2000). The letter created a mechanism to differ from standards and guidelines but was not widely adopted as other barriers appeared to come into play.

Second, some people saw adaptive management as a public participation process only. Specific collaborative goals were included in the Plan (in part because of the success of the pioneering community collaborative efforts in the Applegate Valley, Oregon), as a means for planning and accomplishing projects. Many of the adaptive management areas created new partnerships working through the new provincial advisory committees established by the Plan. The organized dialogue between managers of different agencies, regulators, and different constituencies improved communication and understanding between these players. Expectations of reaching consensus or implementing consensus ideas on the ground were not often met, however. Many of the partnerships have lost momentum in the last few years (Stankey and others 2003). Note that multiple efforts involving the public were undertaken outside of the adaptive management areas as well.

Third, precaution trumped adaptation. In contrast to the precautionary principle, adaptive management embraces risk and uncertainty as opportunities for building understanding that might ultimately reduce potential risks (Stankey and others 2003). Withholding action until more is known is a rational response to uncertainty in many instances, but undue concerns with avoiding risk and uncertainty can suppress the experimental policies and actions needed to increase understanding. When minimizing the possibility of failure dominates policy and management processes, uncertainty is traded for a "spurious certitude" that provides a comforting, but illusionary, sense of predictability and control (Gunderson 1999a, Wildavsky 1988). Although the Plan's precautionary strategy might be assumed to be the most viable approach to long-term protection of declining species, another perspective is to treat this assumption as a "question masquerading as an answer" (Gunderson 1999b).

Finally, regardless of good intentions, sufficient resources were not available to implement adaptive management as envisioned by FEMAT scientists or by the implementation team (Bormann and others 1994). Causes of inadequate funding are complex. Various Plan requirements, such as watershed analyses and the Survey and Manage program, consumed many of the available resources early on. Writing complex decision documents, responding to continuing lawsuits, and regulatory consultations also consumed time of agency specialists. Decreased timber harvests reduced receipts that might have been used for monitoring projects on adaptive management areas on USDA Forest Service (FS) lands. The most powerful evidence to consider is the decline in FS positions—a loss of more than 70 percent of the full-time employees on some Plan forests since 1990 (chapter 3). Reduced budgets made centralization attractive, and several forests and numerous ranger district offices were combined. Workforce motivation in this environment, especially to meet needs perceived as additional—like adaptive management—would be difficult for any organization. This context suggests that the agencies' decision to allocate substantial resources to the regional monitoring reflected a serious commitment to at least one aspect of adaptive management.

Examples of unfolding, potential successes of active adaptive management (as envisioned by researchers and some managers) can be found, despite all the problems. For example, the Blue River landscape management project, currently being implemented in the Central Cascades Adaptive Management Area, helped develop a landscape prescription for matrix lands based on a disturbance ecology approach with deviations from standard and guidelines (Cissel and others 1999). The Five Rivers landscape experiment on the Siuslaw National Forest began a 12,000-acre, replicated management experiment testing alternatives to growing late-successional habitat (Bormann and Kiester 2004). The Blue River study continued work that began on the H.J. Andrews experimental forest before the Plan included the forest in an adaptive management area. After gridlock prevented implementing its predecessor in the North Coast Adaptive Management Area, the Five Rivers project was applied outside the adaptive management area (Bormann and Kiester 2004). The Little Horse Peak project in the Goosenest Adaptive Management Area was established to determine the extent to which different combinations of silvicultural treatments (especially tree harvesting and prescribed fire) can accelerate development of late-successional forest attributes in mixed stands of ponderosa pine and white fir; the project is examining responses of many forest attributes, including vegetation, insects, and wildlife. These successes demonstrate that adaptive management can be possible outside of formal adaptive management areas if management-agency leadership and research participation are adequate. As such, they present models for future consideration.

Reflections on Regional Monitoring

Monitoring Observations

A framework for Plan monitoring (Mulder and others 1999) helped shape plans for monitoring a range of resources (Hemstrom and others 1998, Lint and others 1999, Madsen and others 1999, Reeves and others 2004). The interagency monitoring program coordinated all of these regional efforts and took charge of the 10-year interpretive report (5-year reports were mandated by the Plan), consisting of five status and trend (module) reports and this science synthesis. The monitoring program reported on trends in the Plan region over a decade or more in forest vegetation (older forests), implementation, and northern spotted owl modules, and some aspects of socioeconomics and aquatic systems. In parts of other modules, the time series were much shorter; they are considered initial inventories or baselines for now. All monitoring modules have produced results that allow at least preliminary examination of underlying assumptions, conceptual models, analytical tools, development of descriptive or predictive models, and efficiency of protocols used in Plan monitoring.

We briefly express our interpretations of how well the regional monitoring program worked in its first decade. We then present an adaptive-management-oriented conceptual model for monitoring, as a way to look forward to improving monitoring in support of future interpretive 5-year reports. A thorough assessment of the monitoring program is beyond the scope of this chapter, but such an assessment would provide substantial useful information for future decisions. Our retrospective interpretations are:

- Monitoring was the activity making greatest progress in meeting the regional expectations of adaptive management established in the Plan. Monitoring took the first step in moving from opinion toward evidence-based decisions (opinion will always be involved). Monitoring provided the opportunity for using feedback to make midcourse corrections. Adaptive management cannot be done without monitoring; monitoring without adaptive management is just data.
- The Plan helped institutionalize adaptive management at a regional scale through the monitoring program and 10-year interpretive report. This report brought strong focus on what has been learned, improved communication, and raised the chances that knowledge will be incorporated in future planning, implementing, and monitoring, which meet the criteria of McLain and Lee (1996).
- Plan monitoring provided our first estimates of measurement error and underlying variance of key Plan indicators. Sampling strategies can be evaluated for the first time and fine-tuned to become more efficient now that we have an understanding of this variability. Such data are valuable even where significant trends have yet to be observed.
- The regional monitoring program demonstrated that agencies can work together effectively.
- Monitoring was expensive—about $50 million over 12 years (about 17¢ per acre per year). Most resources were focused on continuing owl demographic monitoring (about $25 million).
- The compartmentalizing of monitoring into implementation, effectiveness, and validation monitoring—and then a dominating focus on effectiveness—probably limited learning. Because people believed being “effective” was more important than creating records of activities that

could be assembled for regional analysis or more important than questioning the many assumptions, effectiveness was monitored while record keeping and skepticism waned. Two legs of the monitoring stool were quite weak (implementation monitoring and research efforts notwithstanding).

Monitoring Concepts

We propose a conceptual model for monitoring consistent with evolving ideas about adaptive management, with some minor changes in emphasis from Mulder and others (1999). The most important premise of this model is that the monitoring questions reflect crucial management decisions. The primary purpose of monitoring is to inform future decisions and meet legal obligations, not to do research or public relations. Once the questions are chosen, then the emphasis is on applying the best available technical approaches for data collection and compilation. When technical issues are addressed rigorously, most large-scale ecosystem monitoring will be expensive. Thus, we propose that the ideal set of monitoring questions will:

- Be chosen by accountable decisionmakers (with input from others).
- Be focused on a limited range of possible future decisions.
- Be as durable as possible, so results are still useful when they are finally produced.
- Have quantified expectations laid out in advance, so monitored deviations from expected outcomes can serve to make clear conclusions about changes.
- Reflect a broad spectrum of public opinion.
- Be linked to potential management changes by laying out in advance explicit assumptions and potential management responses.

Monitoring results complete an adaptive management cycle when they influence management decisions. Formal methods for linking decisions to monitoring can facilitate this process. A monitoring program is a proactive strategy for managers to inform and counter external forces driving policy shifts with more internal knowledge. Other, less tangible benefits from monitoring could be considered as well, such as building public trust, cross-checking assumptions, learning about emerging questions, and institutionalizing adaptive management.

Our monitoring model has technical aspects to consider, such as: Do chosen variables answer the question posed? Is monitoring efficient? Is monitoring information effectively summarized and communicated? These questions are addressed briefly before preliminary recommendations are presented.

Do Chosen Variables Answer the Question Posed?

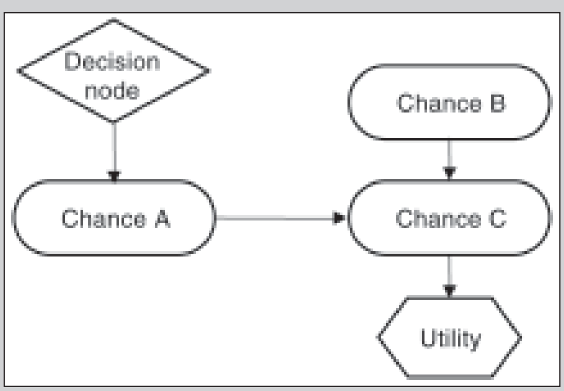
Fundamental to monitoring a large, complex ecosystem is choosing the variables or metrics most appropriate to the questions posed and their scale. Because of spatial and temporal complexity, simply choosing what to measure is not enough; when and where are also important. The Plan embodies conservation goals and implementation standards across 22 million acres of federal land in the Northwest. At the finest resolution, the Plan is implemented with management decisions affecting as little as a few acres or restricted stream segments. The challenge is how to most effectively meet information needs at multiple scales. Ideally, aggregating monitoring information up from local scales would help higher in the hierarchy, and monitoring at large scales would provide valuable context for more localized questions (Busch and Trexler 2003, Morrison and Marcot 1995). Choosing where to measure requires understanding the primary scales of interest to decisionmakers and how inferences change across scales. Clarity about the acceptability of developing stronger inferences where data and analyses can be aggregated to a regional scale, together with acceptance of weaker inferences at smaller scales, would be helpful. Initial monitoring results showed how information on nonfederal lands can serve a more complete ecosystem analysis, which has so far been accomplished only with inventory and remote-sensing data. Because potential responses may play out quickly or slowly, determining if the intensity of data collection can detect

Decision Models

Decision models take various forms. One framework for linking decisions to monitoring (see Lee and Bradshaw, n.d.) involves the use of influence diagrams (Clemen 1996, Howard and Matheson 1981). An influence diagram is intended to represent the decision process in a way that explicitly recognizes the uncertainty in consequences or outcomes of the decision. Influence diagrams consist of nodes or variables connected by directed arrows (below). Three kinds of nodes exist: decision nodes represent alternative actions that might be taken; chance nodes represent events or variables affected by the decision or other chance variables; and value or utility nodes represent variables summarizing the final outcome of a decision. In business decisions, value nodes are often expressed in monetary units. For other kinds of outcomes, the relative benefit offered by a particular outcome is summarized by its utility, a nondimensional metric that allows comparing dissimilar elements (such as, fish versus timber). Relations between outcomes and utility are expressed as utility or preference functions; such functions reflect both comparative value and attitudes about risk (Keeney and Raiffa 1976). Although decisions can be analyzed without explicitly assigning values or utilities to outcomes, the act of choosing one outcome or the other as preferable implicitly reveals a preference function.

An influence diagram is more than simply a schematic representation of the interaction of decisions and chance variables. Well-established statistical methods are used to quantify the strength of causal dependencies by using conditional probability matrices that link chance nodes to decisions or to other chance nodes. Influences are propagated mathematically through the network such that conditional changes in probability at each node are calculated based on the decision option and various input variables. The mathematical framework underlying influence diagrams provides a strong conceptual link to statistics, and a rigorous means of using experimental results or monitoring data to update or verify the diagrams.

Influence diagrams are commonly used to identify the decision option with the highest expected utility given the information in hand, but they have other uses. One purpose they serve is to allow calculating the value of information; that is, they rigorously calculate the change in expected utility given a reduction in uncertainty about a particular chance node. Many businesses use this type of analysis to decide whether investing in additional information gathering or research before making a decision is cost effective. Sensitivity analyses are also easily accommodated, in which the variables most critical to making an optimal decision are identified.



Decision model: a simple influence diagram with one decision node, three chance nodes, and one utility node. Arrows indicate causal dependencies or effects; that is, the decision has a direct influence on chance node A, chance nodes A and B affect C, and utility is derived from C.

projected trends is also important. Monitoring some variables on a nearly continuous basis and others less frequently may also be reasonable.

Is Monitoring Efficient?

The efficiency of monitoring under the conceptual model we use lies with how useful the results were per unit of monitoring effort. Measuring this kind of efficiency is complicated by the time lags between collecting data and considering findings in decisions, and by the various intangibles of decisionmaking. Most effort is therefore usually focused on other forms of efficiency. Several mechanisms were incorporated into the Plan's monitoring program design, with the prospect of making the program operate efficiently, and to become more efficient over time (Mulder and others 1999). Many of the efficiency issues address aspects of the sampling designs.

One tradeoff is between using statistically rigorous sample design compared to scientific consensus. Both were used, and reasons may be found to adjust monitoring program elements toward one approach or the other. Another tradeoff lies between sampling and spatial resolution. For example, study sites were randomly selected, so inferences drawn from the data monitored in the watershed-module applied to the entire Plan region—at the cost of limited spatial and temporal resolution. Risks and benefits of such approaches in all monitoring modules are reasonably well known, so a determination about the desired course for the program as a whole (either change or continuity) should be possible.

Another issue is whether new information about dynamic ecosystems has been incorporated into monitoring design, and if the information needed about disturbance is at odds with monitoring of the Plan's land-use designations. Monitoring programs have not been oriented toward detecting the effects of environmental disturbance or how dynamic environments interact with land-use designations. Despite their focus, some sampling designs may be able to detect change caused by disturbance. Monitoring based on interpreted satellite imagery with complete coverage or based on probabilistic sampling approaches are best suited to conducting analyses on disturbances detected by the monitoring protocols. Sample-size limitations can, however, constrain inferences about types of disturbance at multiple scales (for example, effects of slope failure in key and nonkey watersheds or effects of fire in late-successional reserves versus matrix).

The relative value of monitoring wildlife populations or their habitat is also important. The Plan stressed the role of the FS and USDI Bureau of Land Management (BLM) in managing habitat to provide for viable populations of desired species. Monitoring plans adopted a strategy where habitat models would complement or partially replace some direct monitoring of populations. In addition, watershed monitoring included a strategy where watershed models would obviate the need for extensive instream measurements. The hope was to gain efficiency by using robust databases on both habitat and populations, and by developing models for projecting populations based on habitat condition. At this point, the proportion of the variation in spotted owl population vital rates that can be explained by habitat variables is too small to make reliable predictions about demographic characteristics and, thus, population trend. Some indications suggest that monitoring vegetation may be more reliable in predicting owl and murrelet presence than in predicting populations. Although some differences in watershed condition were apparent across different Plan land-use designations, whether subtle trends in condition will be discernable over time is unclear. Even less certain is that watershed condition will have much predictive value in describing instream factors or aquatic populations. Although better data and better models are unlikely ever to permit complete conversion to habitat-based monitoring, strategic development of models is an important research tool with potential for helping to make predictions and develop cause-and-effect relations.

Another key issue is continuity in the face of changing technology. Recognizing the value of continuity when considering changes to the monitoring program is important. Variables with a longer record or a record that can be retrospectively assessed may be more useful than those of short duration, all else being equal. Changing course in midstream can come at a high price. Wall-to-wall remote-sensing approaches used in the first decade, however, may be at a point for change. The Thematic Mapper satellite is failing. We suggest that some form of three-dimensional measures of forest structure (light detection and ranging [LIDAR] and interferometric synthetic-aperture radar [IFSAR]) linked with digital aerial photography will present the most value for the next decade. This approach can produce positional (x, y, z) data that do not require additional interpretation, at a scale of individual trees.

To ensure long-term success of the Plan, increased emphasis on monitoring that can improve understanding of causes and effects is important. Agency and university researchers attempted to analyze some of the Plan's underlying assumptions, but the process was largely ad hoc. Some cause-and-effect links are possible at regional scales; for example, a stand-replacing disturbance can be compared to management history. Many links are not possible; for example, smaller disturbances cannot be detected with current remote sensing. Confounding factors will always limit cause-effect links; the only way to reduce confounding is through more structured learning (rigorous comparisons in designed management experiments). Few midscale management experiments envisioned for adaptive management areas were designed or implemented (with some notable exceptions). These efforts could be considered part of a system of adaptive management and monitoring in the next decade.

Is Monitoring Information Effectively Summarized and Communicated?

We discussed how change in management direction could be used as evidence of adaptive management. Change in management direction could also be used as evidence of how effectively monitoring information is summarized and communicated. To be fair, judging success or failure now is too early—the status and trend reports and our own synthesis were just released. Nonetheless, we think some opportunities to improve how monitoring is summarized and communicated are available.

Models can help to summarize and characterize understanding, but they are only as good as the data and assumptions they use. Models can help identify and estimate causal relations, quantify strength of evidence for alternative hypotheses, and be used to make (or update) projections for objects of interest. New information accumulated since Plan inception might provide a basis for adjusting models underlying the regional monitoring program. Clearly, some influential factors were less understood before, such as potential barred owl effects on spotted owl populations. Other factors may affect all systems monitored, but they may be thought of as exerting their influences less directly, such as global climate change or forest-marine ecosystem links. Increasing social awareness of issues such as fire and invasive species and activities by managers to address these questions also argue for potential model revisions. Given the above, incorporation of "new" factors in revised models could be considered before changing monitoring protocols. Without this step, discussions of prospective change might not provide sufficient rationale for change, or could be viewed as unjustifiably producing winners and losers in terms of the subsystems monitored.

Lastly, the monitoring program sometimes suffers from a lack of clearly articulated expectations or goals. Information now exists to rectify this shortcoming. For example, the monitoring program has yielded important information on the amount and distribution of old forests under various definitions, on the distribution and abundance of marbled murrelets, on demographic parameters for owls, on watershed condition, and on social and economic conditions throughout the Plan area. Data can now help clarify baselines and targets with greater accuracy than was possible at the beginning of the Plan. Because targets are based on social values and agency policies, decisionmakers need to help articulate them.

The Costs and Benefits of Regional Monitoring

We consider the value of what was a unique experience with regional-scale, interagency monitoring linked directly with land management. The costs of regional monitoring under the Plan were substantial (table 10-1 [by agency] and table 10-2 [by monitoring modules]). Although the total amount ($50 million) is large, the per-acre cost for 12 years was about $2 per acre, or less than 17¢ per acre per year. For the last 4 years, costs have averaged about $6 million per year. The costs are not shared equally across the various modules, however; owl monitoring accounts for half of the total costs. Watershed conditions and marbled murrelet monitoring were the next two most costly. These costs before fiscal year 1999 are underestimated because contributed staff time spent developing monitoring protocols was not accounted for. At the Pacific Northwest Research Station in the early parts of the decade (1994 to 1998), support for developing monitoring protocols and initial monitoring was two to three times what is shown in table 10-2 (see app. 5 in Haynes and Perez 2001). After monitoring began in earnest, this support was reduced as efforts shifted from research to the monitoring program.

To put the costs in perspective, regional monitoring was about 12 percent of the cost of implementing the Plan and about half of what was spent on the Survey and Manage program when it was at its peak. Regional monitoring may also have reduced the costs of local monitoring. The costs are offset by many benefits, especially when monitoring is seen as a vital cog in an adaptive management strategy. Monitoring cannot be judged in isolation but by how well its interpretation is integrated with knowledge from available sources and facilitated decisions on whether course corrections are needed. Although room for improvement clearly exists, we conclude that regional monitoring and its interpretation:

- Complied with specific legal mandates.
- Provided information about progress at a regional scale to help identify when changes should be considered, thereby completing a loop in the adaptive management cycle.
- Provided a venue where managers and researchers can consider recent research findings holistically and in the context of the complex societal and legal environment.
- Began to substitute opinion with data-based evidence, where possible.
- Institutionalized part of an adaptive management system, and—perhaps more important—convinced managers that adaptive management is an integral part of management.
- Provided an opportunity for increased trust between agencies and among constituents by better communicating progress toward achieving broad goals.

Considerations for Future Progress in Adaptive Management and Regional Monitoring

We present some initial ideas to improve the regional monitoring program, as we were asked to do by the regional agency executives. Because regional monitoring is only part of a systematic approach to adaptive management, we then offer ideas on ways to improve adaptive management more generally.

Improving the Monitoring Program's Second Decade

Ways to improve the monitoring program:

- Consider committing to interpreting regional monitoring and research every 10 years, if not more often, to gain the most value from the monitoring effort.
- Consider developing a list of corporate questions to set up the next interpretive report and defining priorities in this list based on decisionmakers' understanding of emerging issues, their vision of future societal goals, and the cost and feasibility of obtaining quality monitoring data.
- Consider developing a new adaptive-management-oriented monitoring framework that includes new monitoring plans with quantitative expectations from experts and others and potential management responses to deviations from expectations (without clear expectations, clear changes cannot be measured or interpreted).

Table 10-1—Plan monitoring expenditures by agency[a] by fiscal year (Oct. 1)

Agency	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
	Thousand dollars												
BLM	549	549	636	625	318	1,272	889	1,313	1,249	1,306	1,294	1,218	11,218
R5	193	193	234	234	209	354	322	774	839	885	995	973	6,205
R6	549	549	635	625	494	1,631	1,332	2,050	2,212	2,326	2,263	2,425	17,091
NPS					68	105	140	190	190	140	140	115	1,088
FWS			20		20	724	481	396	411	416	435	435	3,338
PNW	549	549	549	508	415	876	476	602	630	452	520	607	6,733
PSW						90	270	179	200	200	135	135	1,209
USGS					302	365	234	234	231	226	185	67	1,844
EPA						60	103	90	90	90	120	110	663
NOAA-F						45	0	100	170	170	170	90	745
Total	1,840	1,840	2,074	1,992	1,826	5,522	4,247	5,928	6,222	6,211	6,257	6,175	50,134

[a] Contributing agencies

BLM–OR/WA Bureau of Land Management
R5–USDA FS, Pacific Southwest Region
R6–USDA FS, Pacific Northwest Region
NPS–National Park Service
FWS–US Fish & Wildlife Service Western Region
PNW–USDA FS, Pacific Northwest Research Station
PSW–USDA FS, Pacific Southwest Research Station
USGS–US Geological Survey
EPA–Environmental Protection Agency
NOAA-F–National Oceanic & Atmospheric Administration–Marine Fisheries

Table 10-2—Plan monitoring expenditures by monitoring module

Module	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
	Thousand dollars												
Spotted owl	1,840	1,840	1,840	1,740	1,626	2,291	2,117	2,363	2,553	2,369	2,548	2,612	25,739
Marbled murrelet						1,490	854	1,139	987	767	814	738	6,789
Older forests						752	446	411	486	777	551	433	3,856
Watersheds						422	450	1,426	1,053	1,007	1,252	1,223	6,833
Implementation			234	252	200	250	200	239	263	280	225	216	2,359
Socioeconomics						17	25	140	200	383	400	395	1,560
Biodiversity						75	75	35	58	47	47	27	364
Tribal issues								10	40	58	105	76	289
Program management						225	80	165	582	523	315	455	2,345
Total	1,840	1,840	2,074	1,992	1,826	5,522	4,247	5,928	6,222	6,211	6,257	6,175	50,134

- Consider focusing more effort on agency record keeping, vital to any future interpretive analysis. Our team was not able to assemble existing local activities records, such as thinning and prescribed fire, into a regional analysis, in part because no mechanism to do so existed. We have also seen evidence that previous FS record-keeping systems have been replaced with ad hoc local record keeping.
- Consider ways to overcome obstacles to coordinating monitoring at different scales and from different sources, including projects, management experiments, assessments, inventory, and other federal and state agencies (Busch and Trexler 2003, Morrison and Marcot 1995).
- Consider reallocating some resources to testing assumptions and learning about mechanisms that explain management effects or population trends, in management experiments and mechanism-oriented research; also considering supporting retrospective monitoring by using old agency records.
- Consider promoting multiple methods of quantitatively interpreting monitoring data. Using traditional Neyman-Pearson statistics, Bayesian statistics, and exploratory data analysis helps to strengthen evidence.
- Consider continuing to make data and interpretations widely available.

Changing the Course of Adaptive Management

Whenever scientists and managers get together to discuss large-scale resource management issues, two common refrains are heard. Managers complain that risk-averse policies and regulations limit their ability to manage effectively. Scientists complain insufficient attention is paid to uncertainty, monitoring is underfunded, and rigorous learning from management experience is not valued by risk-averse decisionmakers. Unfortunately, considerable truth lies in both complaints, yet neither perspective is entirely accurate or easily addressed. The precautionary principle is clearly in play in the Plan, and the burden of proof required of managers before they act is perceived as very high, but some avenues for action are clearly permitted in the Plan. Similarly, regional agency executives have made major investments in monitoring and evaluating the Plan's success—for example, this report is a result of the agencies' commitment to a periodic evaluation of what has been learned as a basis for possible change in direction. The path to reduced uncertainty and manageable risk, however, is not the exclusive purview of regional executives, analysts, or science teams.

We suggest several potential adjustments that might further the broad aims of adaptive management, which ultimately is to improve management to meet societal needs. These suggestions augment the various observations made throughout this report. The experience in the Plan's first decade suggests that the effectiveness of adaptive management can be increased by bringing together the wide array of learning and adapting activities into a more coordinated, directed, and institutionalized system designed to be more than the sum of its parts. Many elements started in the first Plan decade need only to be better coordinated in an adaptive system (fig. 10-1). Developing this system will likely require staff work, key decisions, and continual support and nurturing by managers, regulators, and researchers.

Implementing management experiments—
One of the most important, least developed elements of a systematic approach to adaptive management (fig. 10-1) is management experiments (on or off the adaptive management areas). Active adaptive management compares alternate management pathways in management experiments applied, not as research projects, but as well-designed, agency-led administrative studies undertaken as an integral part of management itself. These experiments, conducted on or off adaptive management areas at the normal scale of management, would include alternative strategies or "pathways" to achieve specified goals of the Plan. Management experiments are extensive in that they will not require intensive monitoring as typically required

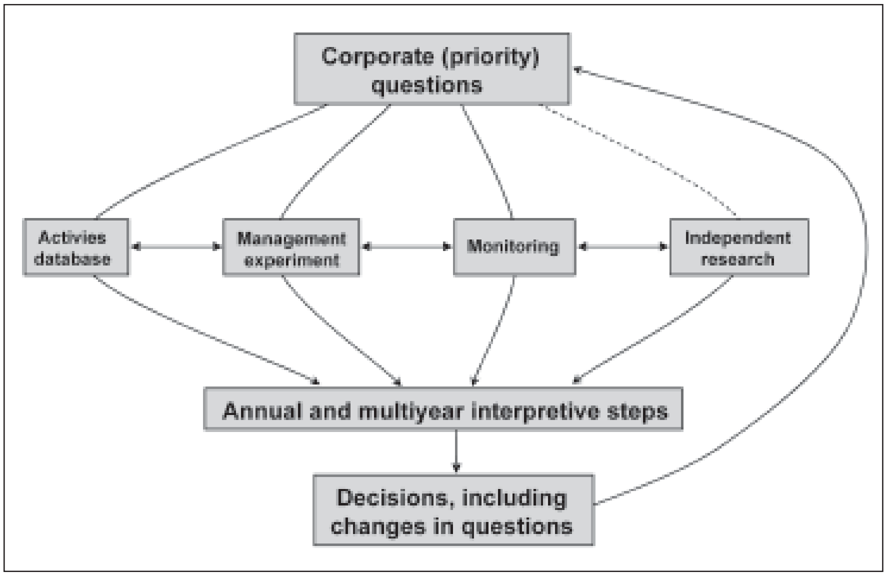


Figure 10-1—A conceptual model for more systematic learning, where corporate questions drive various learning activities that feed into interpretive steps facilitating decisions on whether course changes are needed, as well as on whether to revise the questions.

in research experiments; monitoring will be more in line with project monitoring (such as stand exams, surveys, photointerpretation, and remote sensing). Management experiments offer an opportunity to provide increased understanding of how management causes observed effects. Regional monitoring and even limited-scope research cannot shed much light on these complex cause-effect relations.What can be learned by comparing practical approaches in these trials strongly complements status and trends emerging in regional monitoring and understanding of new mechanisms in research. Comparing alternative pathways also meets the adaptive-management intent of the Plan, to accelerate learning while managing as a way to respond to the high uncertainties associated with implementing approaches never tried before.

Large-scale experiments may be viewed by some people as risky or in violation of the precautionary principle. Management experiments often make more sense at a scale large enough to reflect the complexity of the landscape and the management strategy. Aggressive learning comes from management actions that challenge underlying assumptions and provide sufficient strength of evidence in a timely manner to distinguish between competing hypotheses. Where management experiments need to include treatments that exceed regional standards and guidelines to provide enough contrast, regulatory and court actions may be needed for this flexibility. Not all management experiments need to violate standards and guidelines; they simply contrast alternative approaches to achieving an objective, as in the Siuslaw National Forest's Five Rivers project. The challenges are clear.

Other important ways to learn—
Not all learning will be gained through monitoring or management experiments. Other important opportunities to gain information may lead to management changes as well. First are the opportunities to exploit retrospective observations. The forests we manage today are a legacy of past actions. What can we observe from the various actions and the associated trajectories that forests have followed over the last 50 years through agency records and aerial photography? Second, we could try to explore the considerable knowledge and experience of active management gained on private timberlands. Other insights from indigenous and local communities may also spark important creative leaps in both questions and approaches. Changing the cultures of federal, industry, and private land managers, and also researchers to equally value this observed or existing knowledge will be a challenge.

A More Systematic Approach to Adaptive Management

Key system elements—many of these elements were started in the first Plan decade and need only to be coordinated in a systematic approach (see fig. 3-4):

- **A periodic, formal interpretive step.** This step is needed to integrate and synthesize disparate information from monitoring and other sources over a sufficient period so that decisionmakers can more fully understand the context for truly adaptive course adjustments. In the Plan, 10 years of monitoring and research worked well to fuel the 10-year interpretive step. More frequent interpretive workshops may prove useful as well.
- **A prioritized list of corporate questions and learning objectives.** Because of time lags in monitoring, research, and evaluation, defining questions now for the next interpretation step is critical. Corporate questions are needed to drive multiagency regional monitoring, and subregional learning objectives are needed to direct management experiments.
- **Linkage and balance among corporate learning activities.** Activities need to be linked through the questions and learning objectives. Resources from management and regulatory agencies need to be balanced among the three main activities:
    - **Agency record keeping** clearly describing what management happened that can be assembled for regional analysis in the next interpretive step (including old records).
    - **Regional monitoring** focused on documenting outcomes for a diverse subset of key outputs and conditions (avoiding indicators, if possible), and also yielding information on unexpected changes and uncertainty, and taking advantage of monitoring by others. Publishing quantitative expectations is also essential to interpreting subsequent outcomes.
    - **Management experiments** (on or off adaptive management areas) designed to produce evidence of links between management direction and changes in outputs and conditions and to evaluate alternative pathways (preferably with pathways linked to different constituents).
- **Research explicitly linked to this system.** Research explicitly linked to questions and learning objectives is also an important learning activity (note, unlinked research is also important because it may produce unexpected results of considerable importance and relevance to future decisions). Researchers are well suited to:
    - Help **frame questions, design monitoring, and design management experiments** to guide learning for the next interpretive step.
    - Lead periodic **interpretive steps** to synthesize and integrate available evidence from monitoring and research in a broader, longer term framework.
    - Conduct **retrospective studies** of past management to uncover temporal uncertainties and causes and effects of past management as a basis for looking forward.
    - Conduct **research experiments** that can address more-focused elements of the corporate questions, or to evaluate effects of specific practices.
- **Upward links.** Links are needed to the planning regulations, the environmental management system, and to the national budget-allocation debate (learning is a legitimate agency output).
- **A financial and institutional commitment to producing evidence** of sufficient weight and relevance to counterbalance some of the external forces driving policy change. Consider a fixed percentage of total financial resources (perhaps 15 percent) and developing more administrative processes to make learning and adapting a part of core business (including training, rewarding, and so on).

Obstacles to learning are not easily overcome, as the experience in the Plan thus far attests. We offer the following principles for effective adaptive management and monitoring:

- **Engage multiagency regional executives in guiding learning.** Agency executives and their staffs bring a perspective and authority that is essential to defining the most important questions to be answered in the next decades and to managing regional experimentation and monitoring. Engagement also increases the chance that what is learned will be incorporated in future decisions.
- **Involve regulatory agencies.** Collaboration with regulatory agencies is especially important in facilitating and learning from more controversial management experiments. For example, if management experiments are properly structured and explained, they can be seen as a way to improve environmental conditions or sensitive species' habitat, not as risks to them.
- **Accommodate reasonable disagreements**. Where uncertainty is high and competing social values and constituencies are connected to different bodies of knowledge and experience, consensus on a single management strategy may be an unreasonable goal. Disagreement can be used to develop different strategies for testing, and it can even help to connect back to multiple constituents.
- **Commit to quality record keeping.** A regionally compatible system with a quality matching the current BLM or the old FS total resource inventory system would document land management activities so they can be compiled across the entire region. Securing, properly archiving, and making accessible old records are also vital to learning. Many of these records are disintegrating, and some have been lost. Retrospective studies of long-term processes require these records.
- **Recognize and address local knowledge needs.** Spatial and temporal complexities in the Pacific Northwest region, in subregional landscapes, and even in smaller areas dictate that local evidence and knowledge are important to land management decisions. Local experts and the public are best positioned to identify information needs, and help design site-specific, midscale management experiments to address them. Engaging and supporting community research efforts have the added benefit of building broad-based support for a regional adaptive management program.
- **Organize around a regional monitoring program.** The regional monitoring program has reduced uncertainty and helped agencies apply adaptive management. Other adaptive management activities, such as midscale monitoring and regional and local management experiments, could be coordinated through the regional monitoring program. Linking regional monitoring to record keeping, monitoring at other scales, or by other agencies and research will remain a difficult proposition, requiring significant attention.
- **Build institutional capacity through employee training.** The complexity of planning adaptive management linked to both local and regional monitoring, designing and implementing management experiments, and interpreting monitoring results demands a significant investment in training that crosses scales and agency boundaries. A new within-agency certification system (perhaps building on the silviculture institute concept) might be considered. Boundary spanning assignments might become part of such a system, where field specialists and researchers would work together on relevant research and management experiments.

- **Value continuing partnerships between researchers and managers.** A sustained partnership (more than periodic regional assessments or evaluations) would aid in overcoming traditional barriers between researchers and managers. Learning from management in a scientifically credible way may meet resource objectives and advance science at the same time. In one approach pioneered at Five Rivers, researchers provided advice on designing management experiments and rigorous monitoring techniques and helped with interpretation of data, managers provided leadership and implemented landscape experiments and monitoring, and researchers are providing knowledge from retrospective research on past management and disturbance through peer-reviewed literature (Bormann and Kiester 2004).
- **Develop long-term funding strategies.** Funding will likely remain a major limiting factor for learning (Stankey and others 2003). A rate of investment in learning commensurate with the value of the information obtained is easily justified, but long-term benefits will have to compete against problems of the day. Regional management-agency staff could learn how to better justify adaptive management expenses to their national offices where funding allocations between regions are made. An alternative approach would be to invest a fixed percentage of incoming receipts (from timber sales, recreation passes, and other sources) in increasing the quality of managing the forest. The Coquille Forest Plan proposed a fixed allocation of 15 percent of timber receipts for monitoring. Some constituents have argued that when agencies are allowed to use timber receipts, an incentive is set to perpetually increase timber harvest and benefits to corporations. Such challenges can be countered only by describing the long-term benefits of learning to society and to the forest itself.
- **Reshape the burden of proof and the precautionary principle.** Managers, regulators, and others are not “embracing uncertainty” (Lee 1993) when they place a heavy burden of proof on those who either wish to protect nontimber resources (as in the past) or on those who wish to actively manage forests (as the Plan was implemented). With uncertainties of the magnitude we see, and because chosen approaches have never been tried before, demonstrating proof of either kind is not possible or reasonable. We have also learned in the past decade that doing nothing—by applying the precautionary principle as a regional standard or legal directive—is a choice that has much uncertainty as well, and some potential for highly undesirable outcomes. A different set of burdens could be articulated. (Whether some constituencies and courts can be convinced remains to be seen).
- **Diversify practices.** Uncertainty leads us to try multiple approaches to meet a goal so that all of our eggs are not in one basket. Beyond simple diversification, we have much to learn about more elaborate hedging strategies (chapter 3).
- **Structure learning.** Uncertainty about management outcomes can be reduced through formal methods of learning, applied most effectively not as small-scale research studies but as management itself (in representative areas).
- **Maintain critical mass.** Enough technical expertise (across multiple disciplines) is needed locally to understand local limits to general knowledge and apply complex multiscale management scenarios.
- **Promote social tolerance.** Perhaps the most important method to embrace uncertainty is to create more pluralistic, multiconstituency agencies by simultaneously applying approaches promoted by different constituencies—so that each constituency can see their ideas reflected in at least part of the landscape.

Finally, the Plan's requirement of an interpretive report is an important success that could be continued and considered in the design of other monitoring programs. The report is important because it brings a periodic focus on what was learned, improves communication of what was learned, improves integration of science disciplines and science and management, and raises the chances that knowledge will be incorporated in future planning, implementing, and monitoring. Here is where the agencies have a good chance to meet the criteria of McLain and Lee (1996): producing new understanding, incorporating that knowledge into subsequent actions, and creating venues in which understanding can be communicated.

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Part III

Chapter 11: Key Management Implications of the Northwest Forest Plan

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Introduction

Part III of this volume was prepared to assist the Northwest Forest Plan (Plan) agencies[1] in responding to the monitoring and science information that was recently compiled to examine the effectiveness of the Plan in its first 10 years of implementation. To set the stage for their response to the new information, the Regional Interagency Executive Committee (RIEC) commissioned the authors to review material from the 10-year status and trend monitoring reports along with Parts I and II of this volume, and suggest implications[2] and potential future actions. The purpose was to help the agencies develop an organized, meaningful, and documented response to the new information, and to facilitate the accomplishment of the "adjust" phase of the **adaptive management**[3] sequence of "plan-act-monitor-adjust."

Given the broad scope and scale of the Plan, it is no small task to ascertain the implications of the recently compiled information and to determine how to best move forward on the basis of knowledge gained. This report describes some of the likely implications of the new information and potential responses on key issues. It is not intended to represent an exhaustive catalog of possible actions, nor does it reflect any particular agency position or policy. The goal of this report is simply to provide an initial framework for discussing possible responses, and to facilitate the development of adjustments and improvements.

There are many factors the agencies must address in responding to the recent information. First and foremost, laws (see box 1) and regulations must be followed. For example, the majority of the USDI Bureau of Land Management (BLM) lands within the Plan area are managed under the Oregon and California (O&C) Lands Act, which directed that these lands be managed primarily for timber production under the principles of sustained yield. Management of federal lands is also guided by provisions of the Endangered Species and Clean Water Acts (ESA and CWA), which call for protection of federally listed threatened or endangered species and water resources, respectively. In addition, congressional and administration priorities, and human and financial resources, all have significant influences on policy and management direction for public lands.

The preparers of the Plan were charged by President Clinton to "achieve a balanced and comprehensive policy that recognizes the importance of the forests and timber to the economy and jobs in this region" and to "preserve our precious old-growth forests, which are part of our national heritage and that, once destroyed, can never be replaced" (USDA and USDI 1994). The President set forth five principles to guide interagency development of a management strategy to protect old-growth-related species and produce a sustainable level of timber (see box 2). The basic components of the Plan (see box 3) were intended to provide for long-term habitat conditions for old-forest species (including two ESA-listed species, the northern spotted owl

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[1] The federal agencies responsible for the Northwest Forest Plan are USDA Forest Service, USDI Bureau of Land Management, and USDI National Park Service (land management agencies); USDI Fish and Wildlife Service, USDC NOAA/National Marine Fisheries Service, and the Environmental Protection Agency (EPA) (consulting/regulatory agencies); and USDA Forest Service Pacific Northwest and Pacific Southwest Research Stations, USDI Geological Survey/Western Research Region, and EPA/Western Ecological Research Division (research agencies). Supporting agencies include USDA Natural Resources Conservation Service, Army Corps of Engineers, and USDI Bureau of Indian Affairs.

[2] In this report, "implications" refers to the potential significance of information to agency policies or actions, or what the information suggests may be needed in the future in order to meet the Plan's objectives.

[3] Definitions of bold text can be found in the Glossary.

Box 1—Significant Laws Governing Federal Lands Within the Northwest Forest Plan Area

Clean Air Act Amendments (1990)—Establishes standards for the amount of point and nonpoint pollution that can be released into the atmosphere.

Endangered Species Act [ESA] (1988)—Sets federal procedures for identifying and protecting threatened and endangered plant and animal species.

Federal Lands Policy and Management Act [FLPMA] (1976)—Authorizes the BLM to inventory and manage its public lands in accordance with the principle of multiple use and sustained yield, and requires BLM to complete management plans every 10 years.

Multiple-Use Sustained Yield Act [MUSY] (1960)—Clarifies the Forest Service's broad mission to manage the national forests for recreation, range, timber, water, wildlife, and fish in a combination that will best meet the needs of the American people.

National Environmental Policy Act [NEPA] (1969)—Requires that environmental impact statements accompany all proposed major federal actions significantly affecting the quality of the human environment.

National Forest Management Act [NFMA] (1976)—Requires the Forest Service to prepare management plans for each national forest that meet the requirements of the MUSY to address such matters as nondeclining even flow of timber, biological diversity, land suitability for timber production, and social and economic factors in decisionmaking.

Oregon and California Lands Act [O&C] (1937)—Mandates that the former Oregon and California Railroad Co. lands be managed by the General Land Office (later, the BLM) for sustainable timber production, water quality, and recreation to promote community stability.

Clean Water Act [CWA] (1987)—Establishes standards for the amount of point and nonpoint pollution that is released into the Nation's waters.

Source: Tuchmann and others 1996.

Kath Collier

Northwest Forest Plan Intergovernmental Advisory Committee reviewing a dam removal project on the Olympic National Park.

Box 2—President Clinton's Five Principles for the FEMAT Process

"First, we must never forget the human and the economic dimensions of these problems. Where sound management policies can preserve the health of forest lands, [timber] sales should go forward. Where this requirement cannot be met, we need to do our best to offer new economic opportunities for year-round, high-wage, high-skill jobs.

Second, as we craft a plan, we need to protect the long-term health of our forests, our wildlife, and our waterways. They are...a gift from God; and we hold them in trust for future generations.

Third, our efforts must be, insofar as we are wise enough to know it, scientifically sound, ecological credible, and legally responsible.

Fourth, the plan should produce a predictable and sustainable level of timber sales and nontimber resources that will not degrade or destroy the environment.

Fifth, to achieve these goals, we will do our best, as I said, to make the federal government work together and work for you. We may make mistakes but we will try to end the gridlock within the federal government, and we will insist on collaboration, not confrontation."

Source: FEMAT 1993.

Box 3—Plan Components

Basic Land Allocation–24,877,949* acres (note: there is overlap between some categories):

Congressionally-Reserved Areas-7,291,246* acres. Areas set aside by Congress, such as wildernesses, national wildlife refuges, etc.

Administrative Withdrawals–1,532,605* acres. Areas set aside by local national forest or BLM district plans, such as backcountry recreation or visual areas.

Late-Successional Reserves (LSRs)–7,155,280* acres. Areas reserved to provide a functional, interactive ecosystem of late-successional and old-growth forest. Stand management to enhance or accelerate older forest attributes is allowed up to age 80.

Riparian Reserves–not mapped; estimated in 1994 record of decision (ROD) to be 2,627,500 acres. Zones adjacent to streams, water bodies, and wetlands, where conservation of aquatic and riparian resources is paramount. The width of the zone and the management direction within it may differ.

Adaptive Management Areas (**AMAs)**–1,493,579* acres. Ten areas designated for testing new management approaches and enhanced community involvement.

Matrix–4,043,059* acres (includes small administratively withdrawn areas). Lands where most timber production would occur; includes areas outside of reserves, withdrawals, and AMAs. Includes management direction for retention of smaller fragments of old growth, and also live "leave trees" in harvested areas.

Key Watersheds–10,121,100 acres. Watersheds with special management emphasis for at-risk fish or high-water quality. Key watersheds are a component of the Aquatic Conservation Strategy that overlays the land allocations listed above.

Other Components:

Aquatic Conservation Strategy (ACS)–In addition to the riparian reserve and key watershed land allocations described above, ACS provided for watershed analysis, a procedure to develop information on the ecological function of watersheds. That information is used to refine riparian reserve boundaries, guide land management activities, and prioritize restoration opportunities.

Survey and Manage Guidelines–Guidelines for the inventory and conservation of over 400 rare or uncommon species associated with older forests but not listed under the Endangered Species Act, including amphibians, lichens, bryophytes, fungi, vascular plants, vertebrates, and arthropods. The original provisions have been amended (USDA and USDI 2001, 2004).

Box 3—Plan Components (continued)

Northwest Economic Adjustment Initiative–An effort to provide more than $1 billion of federal funding over 5 years to rural communities to assist them in adjusting to the lower timber harvest levels under the Plan. The funds were provided for infrastructure development, technical and financial assistance to businesses, retraining, and creation of new jobs.

Regional Monitoring–A program of monitoring across the Plan area to evaluate the implementation and efficacy of the Plan.

*Source: "Net Change in Acres by Plan Land Use Allocation Category," 2002 data report at www.reo.gov/gis/data/gisdata/final_lua/LUA_acreage.htm. Matrix acreage was calculated by subtracting the 1994 ROD estimate for riparian reserves from the "other" category.

and the marbled murrelet; see appendix for scientific names), a connected late-successional and old-growth forest ecosystem, and habitats for anadromous and other fish species of concern. The Plan is also focused on goals for sustained production of timber and other commodities in order to accommodate a wide variety of public uses and support jobs and the social well-being of communities within the region over the long term. For a more complete discussion of the goals, components, and implementation of the Plan, see chapter 1 in this volume.

The Plan was constructed with the principle of adaptive management in mind (Bormann and others 1994, USDA and USDI 1994). Any large-scale plan contains considerable uncertainty, and there are unavoidable risks associated with making decisions (including decisions *not* to act) when information is lacking. During development of the Plan, measures were taken to limit risk and reduce uncertainty. For example, the precautionary principle[4] is implicit in the Forest Ecosystem Management Assessment Team (FEMAT) report, resulting in options ranging from a medium to a very high probability of ensuring the viability of species. In addition, the Plan provided a mechanism to conduct monitoring and research that would help evaluate the goals and assumptions underlying the Plan, and reduce uncertainty for future decisions.

The Plan is a long-term strategy, with some goals likely only achievable over 100 years or more (for example, development of old-growth conditions in younger parts of late-successional reserves [LSRs]). The information collected since 1994 represents only the first decade of that timespan. Some of the available information represents just a few years of study within that first decade, and therefore may not be "ripe" for application through an adaptive process at this time. Some tendencies and trends are beginning to emerge, but for many issues, it is too early to tell what the long-term results of the Plan will be. The agencies do have a better picture of information gaps (for example, the need to better understand the influence of barred owls on northern spotted owl population trends) that will help improve the ability of future monitoring and research to support land management policies and decisions. And the agencies now have a better ability to prepare for the next decadal cycle of Plan implementation and adjustment.

[4] There are various articulations of the "precautionary principle." The Rio Declaration of 1992 (United Nations Conference on Environment and Development) states: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

The Plan agencies have a variety of options to consider as they continue to implement the Plan (see box 4). These options would likely be combined to produce a mix of complementary actions. The intent of this part of the synthesis is to provide a foundation from which to begin framing subsequent actions within the realities of agency goals, resources, and capabilities.

Overview of Implications

One of the primary objectives of the 10-year status and trend monitoring reports and synthesis was to determine to what extent the assumptions and components of the Plan had actually contributed to meeting the goals identified in the Plan. Another key objective was to determine what changes might be needed to better achieve the Plan's goals. After 10 years, the information suggests that some parts of the Plan are producing the desired results, some are not, and for some, it is too early to tell. In many cases, external factors (for example, the consequences of the rapid increase in the regional population over the last 10 years) have made it difficult to separate the effects of the Plan from other influences.

The need to sort out subregional variation (at a range of scales from provinces to watersheds) while maintaining resonance with the overall regional strategy is one of the key general implications of the 10-year monitoring and science synthesis reports. In particular, the "fire-prone" provinces and riparian areas have been singled out as places where management direction deserves a second look. Human communities may also differ in their response to the Plan and other influences on a subregional basis.

Although the monitoring and new science information reveals considerable success in meeting Plan goals related to environmental protection and conservation, it

Box 4—Categories of Agency Options for Responding to Management Implications of Monitoring and New Science Information

Option category	Description
Regional policy	Policy decisions made by federal agencies
Program direction	Agency direction for individual programs, administrative actions, budget priorities, best management practices, etc.
Land management planning	Establishment of desired future conditions, objectives, management areas, standards/guidelines, suitability, monitoring, etc. through land management planning processes. "The Northwest Forest Plan," although sanctioned as a term by the Regional Interagency Executive Committee and commonly understood as the regional strategy that guides the management of Forest Service and Bureau of Land Management (BLM) lands within the range of the northern spotted owl, was actually legally embedded and continues its life in the various land management plans for national forests and BLM districts under NEPA. Significant changes to "the Plan" involve amending these plans either collectively or individually.
Research	Development of science-based knowledge
Assessments	Compilation of information and analysis to support decisions or develop options

NEPA = National Environmental Policy Act.

also indicates that many of the social and economic goals, such as timber outputs, were not met. In addition, it indicates a clear need for improvements in some areas, such as risk reduction in fire-prone areas. One challenge for the agencies after 10 years of implementing the Plan is finding the balance between retention of the aspects of the Plan that currently appear successful, and making improvements on the basis of new information. Because the Plan was intended to be adjusted as uncertainty is reduced or as new issues emerge, the agencies are (and will continue to be) considering how to improve implementation through agency plan amendment and revision processes.

Implications for the Scope of the Plan[5]

The Complementary Roles of Federal and Nonfederal Lands

For many Plan goals, consideration of what federal lands can provide reveals only part of the picture. Examples of issues that occur across multiple ownerships include conservation of anadromous salmonids, timber production, and invasive species. Questions have been raised about whether these issues can actually be resolved through a plan that addresses only federal policies and practices. Information accumulated in the last 10 years indicates that state and private management of nonfederal lands significantly contributes to achievement of Plan goals for old-growth forests, endangered species, biodiversity, watershed conditions, and socioeconomic factors.

A better understanding of the role of federal forests within the broader context of all forest lands in the region could help federal managers refine their objectives within the greater regional picture (fig. 11-1). A broad spectrum of forest owners, managers, and policymakers could be engaged to craft a vision of how to collectively meet management goals, or even to craft new goals. Such an effort would provide the opportunity for a different public dialogue about the purpose and roles of the various entities (state and federal agencies with varying mandates, industrial lands, and small private forests) of forest ownership on the Pacific Northwest. Specific questions might include: What are the likely ecological and socioeconomic impacts of changes to the Plan on nonfederal lands? And, how do land management and land-use changes on nonfederal lands affect conditions within the federal forest lands? Such discussions could help inform management decisions across the landscape.

New tools are available to facilitate an improved understanding of broad-scale issues, such as spatially explicit landscape models that simulate the effects of alternative policy scenarios through time on various resources, that facilitate modeling the outcomes of change through time across broad areas, and that project consequences of unpredictable events like disturbances. These tools could help clarify the ability of federal forests to contribute to

Box 5—Plan Scope and Scale Findings

- Many of the ecological, social, and economic goals of the Plan cannot be met on federal forest lands alone.
- Exclusive focus on older forests in the Plan has not achieved a comprehensive strategy for federal forest ecosystems, and leaves unanswered questions about the fate of important landscape components such as mid- and early-seral vegetation, hardwoods, and nonforest plant communities.
- Mitigations for emerging threats, including those from global climate cycles and invasive species, were not built into the Plan, which could significantly affect the long-term ability to meet management goals.

[5] Findings for this section are from various chapters in parts I and II, this volume.

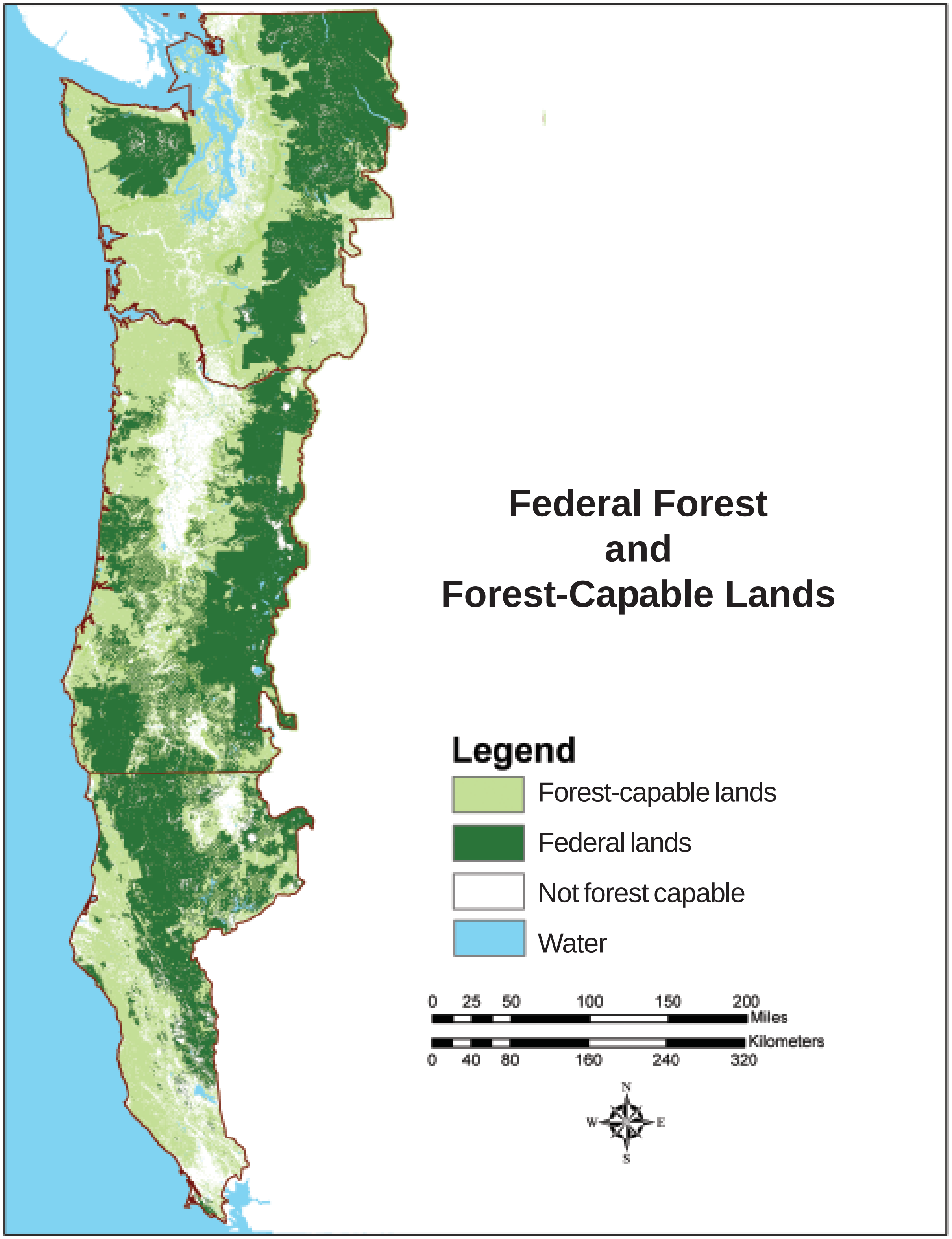

Figure 11-1—Federal forest lands within the Northwest Forest Plan Area. Note that 48 percent of the forested lands are federally managed.

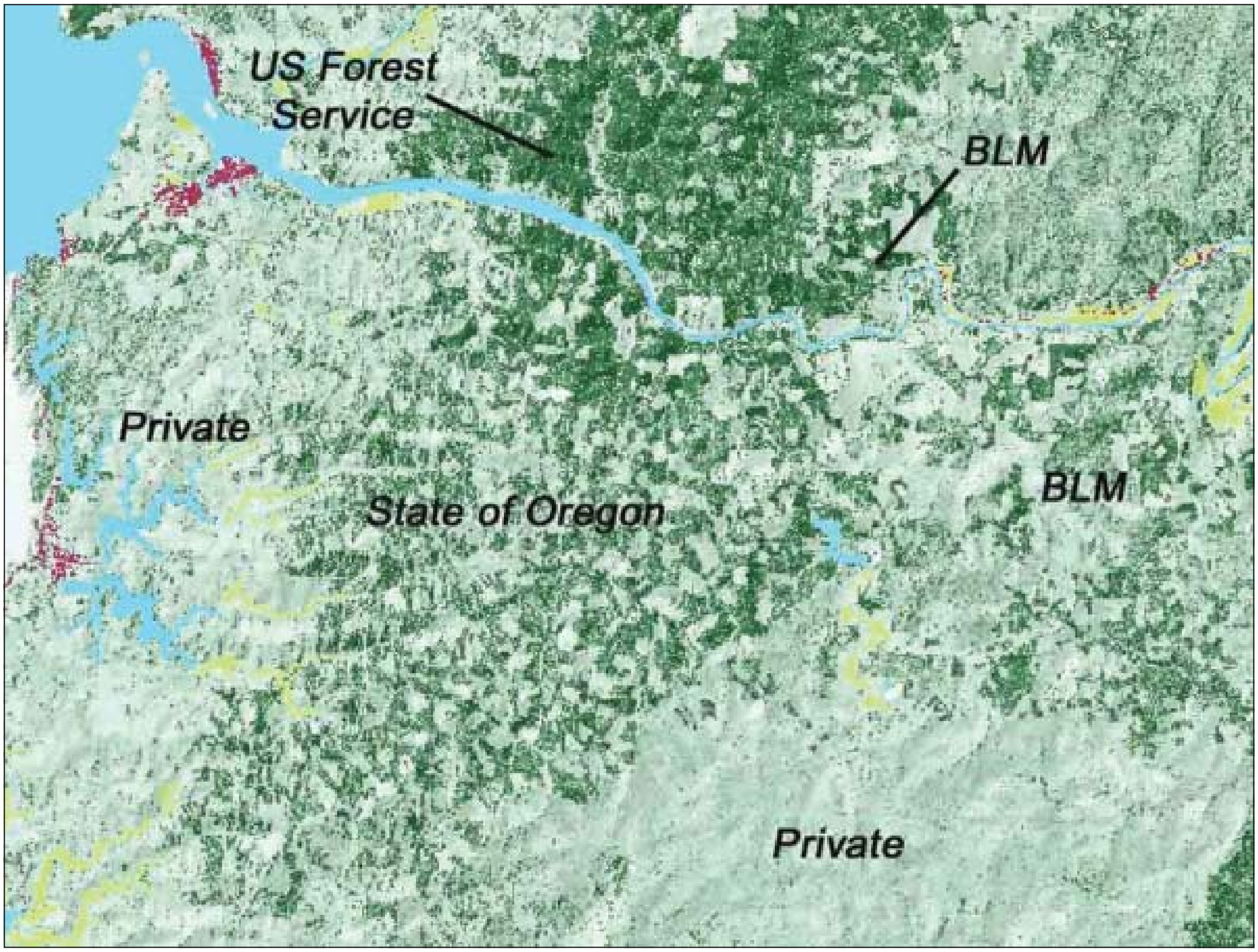

Figure 11-2—Darker green shows area of large trees near Reedsport Oregon. Light green shows area with small trees. The contrast between federal and private management has become greater since 1994.

ecological and economic goals within subregions of the Plan area, and to identify mutual influences among landowners and managers. Some of these tools present challenges in terms of data requirements, cost effectiveness, and clarity.

Beyond Old Growth?

New information about the importance of different forest age classes and nonforest vegetation types suggests that a comprehensive, integrated strategy for managing forest ecosystems should not focus exclusively on older forests. Examples of new findings include the emerging picture of the implications of "bifurcated" forest conditions (only older or young forest) caused by differences between federal and nonfederal policies and land management (fig. 11-2), the increasing threat of invasive species, and growing appreciation of the ecological roles of hardwood and nonforest vegetation types. Limiting the focus to older forests, and ignoring either the earlier developmental vegetation stages that lead up to it or the overall landscape complexity that provides its context, potentially leaves large gaps in the ability to plan and predict future landscape conditions.

Although the FEMAT science assessment that preceded development of the Plan focused primarily on conservation of older forests and associated species, timber harvest, and water resource protection, the USDA Forest Service (FS) and the BLM address a broad spectrum of other resources and forest uses, (recreation, grazing, and mining, for example) in their land and resource management plans. In the process of revising these plans, the agencies could reconsider how to address the full range of forest management issues in light of new findings about broad landscape objectives.

Emerging Threats

Since the FEMAT science assessment was completed in the early 1990s, awareness of the threats of climate change and invasive species to Pacific Northwest forest ecosystems have increased. These emerging threats were acknowledged as a source of uncertainty during development of the Plan, and remain so. The most likely departures from expected future outcomes caused by climate change would be in the drier forests and at higher elevations. New information has shed some light on invasive species; for example, barred owls, sudden oak death, and avian flu virus have been identified as emerging or potential threats to the northern spotted owl.

Climate change and invasive species could have broad-scale and long-term resource management consequences. Additional review of their potential effects on the ability to achieve Plan goals could help inform agency planning processes as science information becomes available that reduces uncertainty in these areas. The nature, extent, timing, and specific effects of emerging threats are still uncertain, and the reports do not specify the level of urgency, or the kinds of actions that could be taken in response. Both the BLM and the FS have programs for managing invasive species, pathogens, and other biological invaders. All of these programs have data available that could be used to assess current and future problems that are likely to affect the ability to meet the Plan goals.

Implications About Plan Components and Issues

Social and Economic Implications[6]

The economic and social context of federal forest lands in the Pacific Northwest has clearly changed in the last decade. In the socioeconomic arena, there were significant differences between Plan expectations and what actually occurred as a consequence of the Plan and other factors. The more striking departures were related to federal timber harvest, the regional timber economy, and communities considered dependent on federal timber production. Much of the information (see box 6) about the social and economic implications of the Plan contained in the *Socioeconomic Monitoring Results* (Charnley and others 2006) and synthesis (chapter 5, this volume) reflects this, challenging earlier notions about the relationship between federal land management, the regional economy, and communities near federal forest lands. A greater understanding of the variety of economic benefits from federal forest lands (besides timber products) would help to improve forecasting of economic impacts. This includes service industries supporting recreation (for example, outfitters/guides, the ski industry, etc.), municipal water supplies, and grazing, among others.

An important part of the agencies' efforts to position themselves for the future will be to find ways to factor this evolving picture of the economic and social role of federal lands and resources into policies, plans, and decisions. This includes more explicitly differentiating between factors that are and are not within the influence of federal land managers. Future planning and implementation efforts would also benefit from inclusion of new information about community resilience and adaptability, and about what being "forest based" actually means for individual communities. There currently are significant gaps in this information for specific communities.

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[6] Findings in this section are from Charnley and others 2006, and chapter 5 in this volume.

Box 6—Socioeconomic Findings

- Federal timber harvest in the last decade was lower than expected, averaging 54 percent of the probable sale quantity over the first decade, owing in part to increasing costs and litigation.
- The effect of the reduced timber harvest under the Plan on rural communities was mitigated to some extent by changes in the regional economy. The overall regional economy grew, but at the same time, some individuals and communities experienced significant negative impacts.
- Local communities were found to be generally more dynamic and varied than was expected, and were influenced by a broader set of factors (including nonfederal contributions to the economy), and are influenced by a wider range of forest uses (in addition to timber harvest) than was originally expected. The concept of "forest-dependent communities" is evolving to include economic ties to forests that are based on recreation and other amenities in addition to wood products, and to reflect local living traditions and the sense of place held by many communities.
- Changes in socioeconomic well-being of rural communities varied during the first decade of the Plan. In one-third of the 1,314 non-metropolitan communities in the Plan area, socioeconomic well-being scores improved, one-third declined, and one-third stayed the same. For communities located within 5 miles of federal forests, socioeconomic well-being scores decreased for 40 percent, increased for 37 percent, and stayed the same for 23 percent.
- The prevailing social paradigm for forest management has evolved. At the onset of the Plan, it was transitioning from "sustained yield" to "ecosystem management," and now seems to be moving more toward "sustainability." In addition, societal values about the importance of old growth have changed, and the viewpoint of "no harvest of old growth" is apparently becoming increasingly acceptable to a larger segment of society.
- There have been significant changes in the timber industry over the life of the Plan, including changes in the infrastructure. The strong link between the timber production infrastructure and communities adjacent to federal forest lands no longer exists as it did in previous decades; for example, a higher proportion of mills is now located near major transportation routes, rather than near forest lands.

Source: Charnley and others 2006; chapter 5, this volume.

Box 7—Components of Community Well-Being Index

The following indicators were combined into an index used to assess the relative well-being of forest-based communities in the Plan area:

- Diversity of employment by industry (the variety of industries that employ people from a particular community)
- Percentage of population 25 years and older having a bachelor's degree or higher
- Percentage of the population unemployed
- Percentage of persons living below the poverty level
- Household income inequality (a measure of the disparity between high- and low-income households)
- Average travel time to work

Source: Charnley and others 2006.

Population has increased by 20 percent in the past 10 years, mostly in urban areas. But many of these areas are close to federal forest.

Susan Charnley

The population and socioeconomic well-being of about 40 percent of small towns near federal forest lands declined over the past 10 years.

Progress on the Plan goal of protecting the environment and creating jobs by investing in locally based restoration, research, and stewardship was less than was hoped for. Improvements could be made by identifying and addressing the institutional barriers that make it hard for agencies to create forest-based jobs that local community members can obtain and by strengthening the links between the Plan's biophysical and socioeconomic goals, to increase community engagement in forest management.

Implications for the Management of Late-Successional and Old-Growth Forest Structure[7]

What is old growth?—

One finding of the research synthesis is that the terms "old-growth," "late-successional forest," "older forest," etc. do not have the same meaning for everyone who uses them. As more members of the public become interested in conserving old forests, the definitions have taken on additional

[7] Findings in this section are from Moeur and others 2005, and chapter 6, this volume.

Box 8—Findings About Older Forests

The current network of late-successional reserves (LSRs) appears effective at protecting the best large, most connected blocks of remaining older forest.

- A significant amount of high-quality, smaller fragments of old forest exists in matrix lands.
- The structure, composition, and dynamics of older forests differ across the Plan area.
- Current management of older forest and LSRs in "fire-prone" areas is not in line with the current understanding of ecosystem conditions and processes.
- At the current rate of thinning, a large proportion of stands in LSRs needing density reduction for fire risk and habitat improvements will move beyond the 80-year window before they are treated.
- Measures to reduce fire risk may also locally reduce the quality of habitat for owls and other species associated with dense forests.
- The effects of postfire management (including salvage logging) in LSRs are not well-understood.
- There is lack of clarity and consensus regarding the definitions of "late successional" and "old growth." This results in different maps and analysis outputs, depending on whose definition is used.

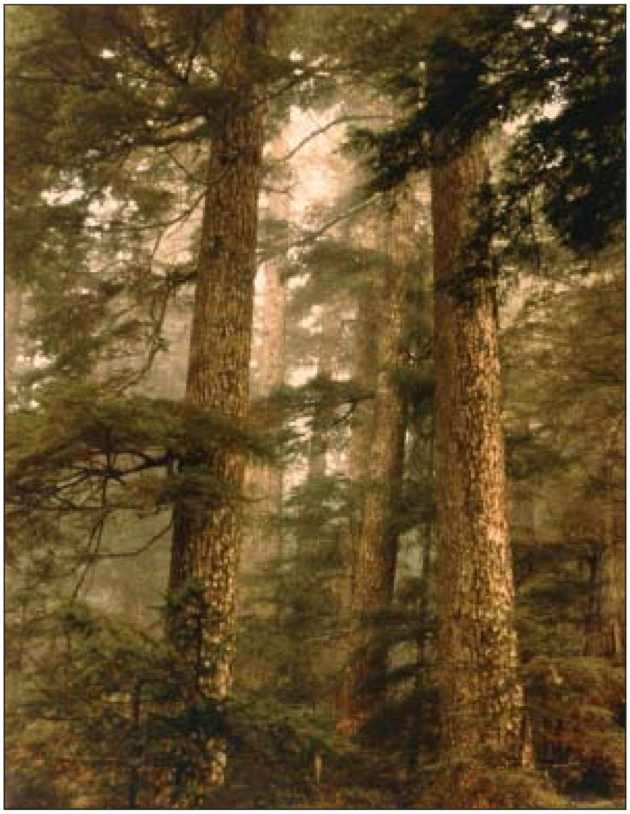
Source: Moeur and others 2005; chapter 6, this volume.

social and political meanings, besides the strictly ecological ones. From an implementation point of view, the Plan does provide clear direction through standards and guidelines. There is, however, disagreement (as evidenced by litigation) regarding how much should be conserved. New knowledge about the considerable complexity and variability of older forests across the region only makes the situation more complicated. Furthermore, the challenging question of how to define old growth in forest types that have been altered by fire exclusion, or are subject to frequent disturbances, remains.

A joint effort by scientists and others to reach a common understanding of the diverse meanings of these terms, and of the diverse forest conditions they represent, could help sort out some of the confusion and imprecision. Ways to represent the social values of older forests may be found during such a process. There is a pressing need for those engaged in federal land planning processes to be aware of which definitions are being used by the various parties, and for the Plan agencies to seek common ground among those involved in developing and implementing plans for the future.

Older forest conservation and management—
As indicated by FEMAT (1993) and Moeur and others (2005), older forests in the Pacific Northwest have been significantly reduced and fragmented by settlement, fires, and pre-Plan logging, and federal lands contain most of the remaining high-quality late-successional and old-growth forest in the region. Conservation of older forests remains both an important societal goal and a necessary element of meeting the ecological objectives of federal land management.

The Plan's strategy of reserves (LSRs in conjunction with congressionally and administratively reserved areas) and management direction for matrix lands appears to be having the intended effect of protecting older forests. But there is both sufficient uncertainty about long-term outcomes, and evidence of problems in the fire-prone provinces, to suggest a need to continue to selectively test and compare alternative approaches at the appropriate scale and with due attention to the risks. The new science findings suggest that active management is likely needed in both young and mature stands in LSRs where stand densities greatly exceed that which would have occurred naturally, to restore ecological conditions and reduce the



Jon R. Martin

Old-growth western hemlock forest.

Steve Lanigan

Aquatic monitoring crew measuring down wood in an old growth forest.

Dave Baker

Stakeholders discuss late-successional reserve management.

potential for loss to catastrophic fires. A dual framework of improving on the Plan's existing reserve component and testing alternative approaches would be one way for the agencies to determine what kinds of (and also where) active management activities would be appropriate. Several alternative approaches for conservation of older forests have been proposed (for example see chapter 6, this volume), but most are largely untested. Options differ in the degree of risk to older forest values and tradeoffs with commodity production.

Approaches such as structure-based management or temporary reserves that result in a "shifting mosaic" of forest age classes (and that may include the use of long **rotations**) could be considered where stronger emphasis on timber production is indicated. These and other alternative approaches could be considered as part of a disturbance ecology strategy to manage for the natural range of conditions at a provincial or watershed scale, and could yield significant new information that would be useful in adjusting management direction. Consideration of information on local ecology and local conditions is an important element of these approaches.

In addition, further consideration of the variation and complexity of older forests across provinces or watersheds

Tom Kogut

Young stand marked for commercial thinning to enhance large tree growth, Gifford Pinchot National Forest.

Tom Kogut

Areas that has been commercially thinned to enhance growth of large trees, Gifford Pinchot National Forest.

could improve the overall late-successional, old-growth forest management component of the Plan. This could result in guidelines for adjusting LSR boundaries where appropriate, and in solving some of the problems associated with current LSR management in fire-prone areas. A new look at the 80-year threshold for LSR stand treatments in areas where later thinnings might still have beneficial effects to stand structure (for habitats) is also ripe for consideration.

It bears noting that there has been significantly less harvest of older forests in matrix lands than was anticipated by the Plan, largely because of litigation. Some have suggested that more emphasis on thinning in younger stands would in part make up for the loss of the timber harvest that was expected and help mitigate the economic effects. Although this might be a short-term solution, longer term economic and harvest projections indicate that the supply of timber appropriate for thinning is limited and will not sustain the targeted levels currently expected under the Plan over the long term.

The problem of the "fire-prone" provinces—

A key question in the management of older forests in the fire-prone provinces is how to simultaneously, across the landscape, provide dense old-forest habitat for species like the northern spotted owl, while minimizing the risk of loss from wildfire. Some of the new information suggests that in northern California and southwest Oregon, low-intensity fire may actually enhance habitat for old-growth species like the northern spotted owl if it creates a favorable mix of successional stages (Franklin and others 2002). There is a significant amount of recent information on older forest ecology to support a new look at how conservation goals could be better achieved in light of the significant risk of loss from wildfire without compromising the integrity of the overall Plan. A provincial- or watershed-scale look at management of older forests (especially an evaluation of LSRs and matrix guidelines) is needed for the fire-prone provinces, that is (1) geared to reducing fire risk at a landscape level; (2) reflective of local environmental conditions, forest structure/composition, and ecological processes; and (3) realistic in regard to what is actually ecologically sustainable in these landscapes. Such an effort could address:

- Areas where there is a need for active management to restore old-forest conditions.
- Guidelines to address the conflict between protecting habitat for species that require more dense, multistoried forests, and the risk of loss to fires.
- Habitats for special-status species that require a long time to recolonize after a disturbance in order to persist (for example, some lichen species).

Note forest ranger in this 1920s photo from the Gotchen Area on the dry, east side of the Gifford Pinchot National Forest.

Today, fir trees have encroached on pine stands in the Gotchen Area of the Gifford Pinchot National Forest.

- Risks of various management activities to other resources and property.

The agencies are already making significant efforts to address these issues.

Postfire timber harvest in LSRs—

Current information shows that there can be considerable ecological value in leaving down wood and snags and minimizing ground disturbance after a fire. At the same time, there can also be economic and fuels reduction benefits from conducting well-designed fire salvage operations that retain appropriate levels of down wood and snags. There is variation in likely results of salvage logging across the Plan area, depending on postfire conditions and other factors. There are substantial gaps in our understanding of the effects of salvage logging and other postfire activities and few opportunities to implement rigorous studies. A partnership between the science and management agencies (such as those that developed following the Timbered Rock and Biscuit Fires) to identify and answer key questions about the effectiveness and consequences of various postfire activities and about the balance between the ecological and economic values of down wood and snags could provide scientific information needed to reduce uncertainty and support future policy development. Litigation experience suggests that postfire salvage is particularly controversial in LSRs, and in those areas, some people's underlying concerns may go beyond the issues of the ecological or economic values of down wood.

Implications for the Conservation of Species Associated With Older Forests[8]

ESA-listed species: northern spotted owls and marbled murrelets—

The protections put into place by the Plan for late-successional and old-growth-related species appear to be succeeding at reducing the rate of habitat loss of federal forest lands. In addition to the Plan's measures, there have been less timber harvest and fewer stand-replacing fires than anticipated. Thus, federal lands are producing older forest habitat at or above expectations, and it has increased over the first decade. Recent science information has raised new questions about what constitutes old-forest habitat for different species (for example, in northern California, habitat heterogeneity appears to be more important for

[8] Findings in this section are from Lint 2005; Huff and others 2006, and chapters 7 and 8, this volume.

Dave Baker

Deciding on the best forest management treatment following wildfire is a challenge.

Box 9—Species Conservation Findings

The reserve system is succeeding at conserving and restoring habitat for spotted owls and marbled murrelets.

- In southwest Oregon and northern California, a mix of forest age classes appears to be important for spotted owls, probably owing to greater abundance of prey in more open areas.
- Spotted owl populations were shown to be level to declining for the decade in different parts of the region, and there is uncertainty about both the causes and the long-term consequences of the trends.
- Fire remains a risk to older forest habitats, and there has been a small amount of fuel reduction treatments relative to the need.
- There are uncertainties about the inland geographic distribution of the marbled murrelet, and some areas classified as murrelet habitat may actually be outside the range.
- The population trends observed over the last 10 years for spotted owls and murrelets may not continue into the future.
- New science information on substitutes for a fine-filter conservation approach (for example, use of surrogates or indicators; protection of biodiversity “hot spots”) revealed some problems, including uncertainty about the ability to make inferences for other species.
- Continuing a combined coarse- and fine-filter approach seems called for given the remaining uncertainty about the status of nonlisted rare and uncommon older forest species.

Source: Lint 2005; Huff and others 2006; chapters 7 and 8, this volume.

northern spotted owl populations than in other parts of the Plan area), and there are new concerns about the ability to mitigate fire risk.

Discerning long-term population trends for the northern spotted owl and marbled murrelet after only 10 years is difficult, and the causes of the observed 10-year findings are unclear. In spite of the observed habitat increases, some populations of the northern spotted owl are declining, with different trends in demographic performance among the provinces. Although the agencies anticipated a decline of northern spotted owl populations during the short term, it was thought likely that the species would begin to recover over longer periods as old forest habitat increased. What was actually found through monitoring (Lint 2005) was greater than expected northern spotted owl population decline in Washington and northern portions of Oregon, and essentially a level trend in southern Oregon and northern California. No attempt has yet been made to predict the longer term outcomes based on these trends.

In addition, the reports were not able to make a direct correlation between habitat conditions and changes in northern spotted owl populations, and they were inconclusive as to the cause of the declines. Lag effects from prior harvest of suitable habitat, competition with barred owls, and habitat loss from wildfire somewhat confounded the ability to draw tight relationships between the Plan's results and northern spotted owl population trends. The reports did not include recommendations regarding potential changes to the basic conservation strategy underlying the Plan, but did identify opportunities for further study.

Similarly, nonhabitat factors appear to be affecting marbled murrelet population trends. Marbled murrelet populations seem to be stable for now, but with only 3 years of monitoring data, more time is needed to be confident in the estimated trends. As with owls (and other species), murrelets respond to cumulative effects of many interacting factors, such as oil spills, nest predators, and oceanic conditions, in addition to land management actions such as timber harvest that affect their habitat. There are also uncertainties about reproductive success, habitat/population relationships, and predation.


Joe Kulig

Northern spotted owl.


Tom Kogut

Barred owl.

In spite of these complex issues, the current Plan's reserve-based habitat conservation strategy appears to make an important contribution toward meeting goals for these species at this time. There may be other habitat conservation strategies that would also be effective in this regard, and that could be explored and analyzed through agency planning processes. In addition, answering the following questions helps assess the likelihood of success over the long term:

- What factors contribute to the observed trends in populations, especially the declines measured for the northern spotted owl in Washington?
- Do species-habitat relationships differ across the range of environments in the region?
- How can the agencies reduce fire risk and at the same time meet species' needs for dense old-forest habitats?
- How do non-stand-replacing events (low-intensity fires, insect outbreaks, thinnings, etc.) affect species and habitats?
- What are the likely future scenarios with regard to emerging nonhabitat concerns, like barred owls, etc.?
- What is the actual distribution of marbled murrelets in the inland (zone 2) portion of the current range?

An important part of answering these questions will be to overcome the significant challenges presented by the limitations of current remote-sensing technology that make it difficult to efficiently and consistently portray fine-scale habitat changes (for example, from partial timber harvest or non-stand-replacing fires).

Strategies for managing both the northern spotted owls and marbled murrelets on nonfederal lands (such as habitat conservation plans) have been devised with the Plan in mind, but an overall assessment of the relative roles of federal and nonfederal lands in the species' conservation efforts is lacking. This issue is particularly important to conservation planning for the murrelet, which has large amounts of habitat on nonfederal lands. This is a good example of the need for greater understanding of the federal land context, as discussed above. Recovery planning processes for these species could help address these issues.

Other rare and uncommon old-forest-related species— The Plan's ecosystem-based strategy for biodiversity conservation still appears to be a valid approach. At the same time, uncertainty remains about the extent to which the reserve system provides for the persistence of all late-successional and old-growth forest species, especially those that are very rare.

Tom Kogut

Larch Mountain salamander is one of many Survey and Manage species.

Information collected through the Survey and Manage program revealed that for some old-forest species, the reserve system likely does contribute to their persistence, whereas others (mostly the rarest species) appear to warrant continued protection of known sites outside reserves. Further interpretation of this and other information will be helpful in refining species conservation approaches. In addition, information gleaned from these efforts could be useful in improving the statistical design and efficiency of future data collection efforts. Fine-filter conservation approaches are important to maintaining persistence of extremely rare species. Reducing uncertainty through accumulation of additional information on rare and uncommon old-forest-related species would likely lessen the amount of work required on the fine-filter side, focusing fine-filter efforts on those species that are most at risk or rare.[9] The high cost of acquiring this type of data requires the agencies to seriously consider the tradeoffs, given limited resources.

Implications for Aquatic and Riparian Conservation[10]

Because the aquatic and riparian monitoring program was not initiated until well into the first decade, and also because watershed conditions change slowly, it is too early to tell for certain whether Plan assumptions about the Aquatic Conservation Strategy (ACS) relative to riparian reserves and restoration are validated. Early results indicate conditions have improved in many watersheds since the inception of the Plan. Future monitoring results will allow more rigorous assessment of effects of reduced timber harvest and road construction on federal land under the Plan, as compared to the previous decade.

Riparian reserves—

In the case of the riparian reserve system, FEMAT assumed that adjustments to interim reserve boundaries would result in a reserve network more tailored to local conditions and processes. Under the Plan standards and guidelines, an analytical process was developed by the agencies to assess and document adjustments to the interim boundaries. As it turned out, many managers and their staffs felt that the burden of proof for interim boundary adjustment was too high, and the procedural requirements outweighed the benefits of boundary changes (which in many cases were viewed as marginal from an operational perspective). As a result, few interim boundaries were adjusted (one example is in Cissel and others 1999), and an extensive network of fixed-width riparian reserves on virtually all water bodies resulted (although forest stands in some of the reserves were thinned). This illustrates the need to ensure that the procedures developed from Plan direction that are intended to foster flexibility and site specificity are practical, efficient, and cost effective.

An aquatic and watershed conservation strategy focused on permanent, unmanaged, and fixed-width buffers

Box 10–Aquatic/Riparian Findings

The monitoring timeframe (2 to 3 years) was too short to produce statistically significant results, but the monitoring did suggest that the combination of restoration activities and reduction in practices that typically degrade riparian areas and watersheds (timber harvest along streams, high road densities) was sufficient to produce improved watershed condition scores in many cases.

- There were fewer adjustments to interim riparian reserve boundaries and management guidelines than anticipated by Forest Ecosystem Management Assessment Team.
- Given the dynamic nature of riparian areas, permanent, unmanaged forest stream buffers may not be sustainable over the long term. Other approaches may be needed to enhance riparian conditions and aquatic habitats.
- New fish population and habitat information (including findings from the Oregon Coast Range that midseral forests may provide better habitat for fish in some cases than does old growth) suggests that revising the key watershed network be considered.

Source: Gallo and others 2005; chapter 9, this volume.

[9] In the original Plan record of decision, over 400 rare and uncommon species believed to be associated with older forests were provided special inventory and conservation measures through the survey and manage standards and guidelines. Some species were removed from the survey and manage list as information came to light regarding their abundance or lack of association with older forests. In 2004, a supplemental environmnetal impact statement that amended BLM and FS plans ended the Survey and Manage provisions, and 152 species were transferred to the interagency special status species program. Litigation of this action continues as of this writing.

[10] Findings in this section are from Gallo and others 2005, and chapter 9 of this volume.

Terry Lawson

Project designer and contractor discuss log placement to improve aquatic habitat, Trout Creek, Gifford Pinchot National Forest.

on all streams was not originally intended by FEMAT as a long-term approach, and appears inconsistent with the current body of science findings. Chapter 9 of this volume highlights the dynamic nature of Pacific Northwest watersheds, the variability of riparian geomorphology and habitat from site to site, and the complexities of how changes occur across landscapes over time. Current science clearly indicates that aquatic ecosystems do not exist in a steady state, and that a range of conditions occurring through time and space is normal. Furthermore, because the processes that influence riparian and aquatic functions (like fires, storms, landslides, floods, etc.) are asynchronous, and differ in intensity, extent, and effects from one watershed to another, management approaches appropriate to one watershed may not be appropriate in another.

The new information constitutes an important resource for the design of more effective approaches to the conservation and management of riparian systems, especially development of indepth understanding of the functional relationships in particular watersheds, and data-derived target conditions specific to particular watersheds and streams. Much of the new information addresses the importance of smaller headwater streams, landforms, tributary junctions, large wood, routing of debris flow materials, upslope conditions, terrestrial wildlife habitat needs, and disturbance processes. Tools are now available that could help (1) identify the "hot spots" in watersheds that most contribute to or affect the overall function, (2) address the spatial and temporal distribution of ecological conditions in a watershed, and (3) set criteria for refining riparian reserve boundaries and management guidance within them. The challenge will be to revise the current processes or develop a new process that provides for appropriate consideration of this information in a cost-effective framework.

Jack Sleeper

Jack Sleeper

Road removal in Cummins Creek, Siuslaw National Forest to restore valuable riparian and flood-plain processes.

Key watersheds—
Key watersheds were intended to serve as refugia for aquatic species, especially to aid in recovery of ESA-listed fish, as well as to focus on water quality for municipal supplies. They were originally selected based on professional judgment, and relied in part on the assumption that streams in old-growth forests contained the best fish habitat (an assumption that has since been shown to be questionable for some sites in the Oregon Coast Range, see Reeves and others 1995). No attempt has subsequently been made to update the network or test its effectiveness, even though new information on fish populations and habitats has been compiled. As federal agencies review the key watersheds component of the ACS (using National Oceanic and Atmosphere Administration [NOAA]—Fisheries recovery plans as a foundation), incorporation of new information on fish populations would help clarify (1) whether, and what kind of, management direction for key watersheds is appropriate; (2) whether the existing network is meeting the intended goals of the key watershed Plan component; and (3) whether watershed restoration priorities should be reconsidered.


A watershed analysis team getting started.

Watershed Analysis

No comprehensive assessment of the effectiveness of watershed analysis has been developed. However, there seems to be agreement that:

- Under the current interagency federal guide for watershed analysis, a diverse set of approaches and products resulted. An assessment of the utility and cost of various processes and products could provide helpful insights to inform future iterations.
- In general, watershed analysis was not commonly used to provide a basis for adjustment of the interim riparian reserve boundaries, as had been envisioned by FEMAT.
- For the future, watershed analysis provides a logical vehicle for "stepping down" Plan goals to a watershed scale, for doing midscale assessments, and for providing a framework for prioritization of management activities. Some watershed analyses actually did this by "localizing" the Plan's desired future conditions and establishing projects to achieve them.
- Watershed analyses that used a multidisciplinary (rather than interdisciplinary) approach often included conflicting recommendations from staff specialists. This has surfaced as a concern during litigation. It would be helpful to review and address the topic to inform future guidance relative to watershed analyses.

Implications for How the Plan Is Implemented[11]

Adaptive Management

What constitutes "adaptive management"?—
Whether efforts to achieve "adaptive management" under the Plan are considered successful or not depends to some extent on the definition adopted. The term "adaptive management" has been applied to a wide range of activities that involve learning from experience. At the more

[11] Findings in this section are from various chapters in parts I and II of this volume.

Box 11— Adaptive Management Findings

- Plan expectations about adaptive management were only partially fulfilled, in part because of different views on the definition of "adaptive management," and in part because of a perceived or real lack of flexibility to test strategies that departed from Plan management direction (standards and guidelines).
- Alternative approaches to landscape management may need to be considered in the fire-prone parts of the Plan area in order for the goals for older forest ecosystem conservation to be achieved.
- Tools are available to help decisionmakers identify and organize information about uncertainties, and to systematically describe the risks associated with alternative courses of action and the causes of those risks.

Source: Chapter 10, this volume.

Box 12—Suggestions for Improving Adaptive Management

- Incorporate "learning" as an objective in various plans and activities.
- Identify places with a specific objective of testing and learning (like adaptive management areas), where new management approaches could be evaluated.
- Determine how to make testing new approaches easier to accomplish. This could include assessment of existing avenues to engage in management experiments (for example, experimental forests, cooperative research projects with other landowners, etc.) and assessment of perceived or real barriers in existing Plan direction and other policies, funding mechanisms, appropriation rules, etc.
- Give greater weight to long-term benefits of increased knowledge vs. short-term ecological impacts, and assess the risks associated with **not** taking action.
- For specific projects or initiatives, involve partners and stakeholders.
- Consider adoption of an integrated "adaptive management system":
    - Regular compilation, synthesis, and integration of new information.
    - A prioritized list of questions and learning objectives that drive the collection and development of data and information.
    - Connections among:
        - Agency record-keeping activities
        - Regional monitoring
        - Designed management experiments
        - Long-term financial and institutional commitment to (1) develop and use information to support policy formulation and (2) update information

Source: Chapter 10, this volume.

rigorous end of the spectrum, scientifically designed management experiments can be effectively employed to test various strategies and their effects. In a less formal mode, simply tracking and communicating the results of management activities on the ground in an organized way can lead to significant learning and adaptation. No matter where they occur in this spectrum, successful attempts to manage public lands adaptively will likely have the following attributes: (1) development of projects with an explicit intent to learn; (2) wide communication of knowledge gained; (3) future decisions made on the basis of what was learned; and (4) active collaboration by research, management, and regulatory agencies along with other stakeholders. Communication about lessons learned is fundamental to adaptive management, a fact reflected in the large number of workshops and reports that have been produced by the agencies on Plan-related topics over the last decade.

Adaptive management in the Plan—
Besides being in a general sense a primary component of ecosystem management, adaptive management was incorporated into the Plan in part to balance the implicit use of the precautionary principle to address uncertainty. A particular design of reserves and other land allocations was incorporated into the Plan with the expectation that adaptive management would result in adjustments as the growing body of information helped reduce uncertainty. Under the Plan, continued use of the precautionary principle appears to have limited application of adaptive management and resulted in a higher burden of proof regarding benefits of management actions to ecosystems and species than was intended. Passive protective measures have been favored over active management, even when the benefits of active management are quite apparent (for example, use of thinning to reduce fire risk in fire-prone areas or to accelerate the development of late-successional features in younger forest stands). The balance that adaptive management was expected to provide has not been achieved to the degree that was hoped for.

There were many successes with regard to adaptive management, including the implementation of regional monitoring, and the 10-year status and trend reports and science synthesis (this volume). The shortfalls in applying the concept center around the quantity and quality of experimental treatments, documentation of results, and institutionalizing change based on what was learned. Perceived lack of flexibility in Plan direction (including similar application of standards and guidelines inside and outside adaptive management areas [AMA]) and limitations in budget and staff are often given as reasons for the less-than-optimal application of adaptive management. Given the strained fiscal and organizational resources, agencies must focus on testing approaches that are likely to work and that maximize relevant lessons for managers pressured to show tangible results on the ground.

The “plan,” “act,” and “monitor” phases of adaptive management have been applied under the Plan, but the “adjust” phase remains problematic.[12] One contributing reason is the lack of institutionally structured means for documenting and communicating when and why adjustments occur. Others are the lengthy time needed to accumulate enough information to support adjustments, and lack of agreement regarding how much information is needed to do so. There is significant controversy and expense associated with making changes, especially at larger scales where formal Plan amendments or revisions might be needed. Several regional adjustments have already been made to the Plan (for example, changes made to the Survey and Manage program; see USDA and USDI 2001, 2004). An exploration of the balance between the Plan’s prescriptive nature and the flexibility it was intended to provide could yield useful insights for making adaptations. For example, a plan that

[12] The problem with the “adjust” phase of adaptive management is not unique to the Plan. In Oregon, the state agencies responsible for implementing monitoring under the Oregon Plan for Salmon and Watersheds have experienced similar difficulties (IMST 1999, 2001).

prescribes leaving six to eight green trees per acre provides little flexibility, whereas a plan that describes an objective of leaving large snags of a specific decay class to support a population of cavity nesters provides more room for adaptation. Plan flexibility involves uncertainty and risk. Some tolerance of risk is intrinsic to successful adaptive management, which requires acknowledgment that learning in order to improve for the future may mean accepting risks today.

Adaptive management areas—
The 10 AMAs partially fulfilled their intended role. Many AMAs were successful at providing opportunities for learning, and several highly relevant research projects were established. But many of the successes and lessons learned were not communicated widely, and large-scale experimentation was generally lacking. There were many reasons for this, including perceived or actual lack of flexibility to test alternative approaches, difficulty in reaching consensus among collaborators, and limited funding, staffing, and management emphasis. Extensive litigation and varying interpretations of the Plan, particularly regarding the extent to which activities in AMAs may deviate from the standards and guidelines, certainly played a role in making it difficult for the federal agencies to test new practices and take risks.

Some large-scale experimental treatments, involving different configurations of reserves, rotation lengths, and harvest patterns, actually have been installed in areas inside (for example, the Blue River Landscape study in the Central Cascades AMA on the Willamette National Forest) and outside (for example, the Five Rivers Projects on the Siuslaw National Forest) of AMAs. As results are monitored and evaluated, these kinds of studies will significantly contribute to the knowledge base, reduce uncertainty, and support Plan adjustments based on what is learned.

The AMA experience leaves some questions the agencies will need to grapple with if success is to be achieved: Is the specific land allocation of "AMA" really needed to accomplish adaptive management (for example, by providing areas for watershed-scale experiments)? If so, what will make AMAs different from other land allocations and successful in leading to adjustments that improve land management? If AMAs are continued as a defined management area, they need flexibility and commitment of resources to fulfill their intended role. Consideration of other approaches to allowing experimentation and structured learning (especially at larger scales) without the creation of special land allocations may be useful as well.

Development and Testing of New Landscape-Scale Approaches

One of the primary reasons for considering new landscape management approaches (see box 13) is that given the significant ecological, social, and economic variation across the Plan area, the goals could probably be better met if management direction were more tailored to local conditions. In addition, the agencies could gain significant new knowledge to support future improvements by testing alternative landscape approaches, with due attention to designing and implementing activities in such a way that inferences across broader areas can be made.

Modeling, retrospective studies, and compilation of traditional knowledge from Native American tribes are examples of avenues for developing and analyzing alternative landscape strategies in addition to actual management experiments. Another option is development of cooperative partnerships between federal and nonfederal landowners and agencies, to test approaches that may not be implementable on federal lands. In this scenario, federal lands could be used as controls, or to test approaches with a conservation emphasis and less manipulation of forest vegetation, while other alternatives could be tested on lands with fewer restrictions.

Rigorous comparison of various landscape approaches (including the Plan) could help provide a basis for clarifying goals, articulating knowledge gaps, and strengthening future decisions.

Risk and uncertainty—
FEMAT recognized that uncertainty in managing the forests of the Plan area would always exist, and tried to create

Box 13—Landscape-Scale Approaches to Consider for Testing in the Plan Area

- Structure-based management (Oliver 1992): a landscape approach that prescribes proportions of the landscape in different structural classes (regeneration, closed single canopy, understory reinitiation, multilayered, and older forest), which are then achieved through active management that also meets commodity goals.
- Temporary reserves that revert to matrix status after loss from natural disturbances, at which time new reserves would presumably be established.
- Hybrid of disturbance-based management and fixed reserves, for example, Blue River Landscape study (Cissel and others 1999). The details would be specific to particular watersheds.
- Reserve all remaining old growth. Commodity goals would be met from young and middle-aged forests.
- Landscape restoration (more appropriate in the fire-prone provinces). Would likely involve designating certain lands as owl habitat, and then crafting a large-scale fuel treatment plan to achieve both habitat and risk-reduction goals.

Source: Chapter 6, this volume.

a framework of adaptation whereby uncertainty would be reduced over time and the Plan adjusted accordingly. However, benefits could be attained from more explicitly exploring and disclosing risk and uncertainty in decision-making processes than is currently the case. Keys to being successful in this situation include having clear goals, establishing explicit desired future conditions and benchmarks, and rigorously documenting the logic behind decisions when uncertainty exists. New decision-support tools are available to help managers more visibly and systematically factor information about uncertainties into decisions, and to describe the risks associated with alternative courses of action. Better organization and documentation of decisionmaking could be achieved through employment of such tools, and application of adaptive management could provide a structured framework to continually update the tools and make them work more successfully. Use of such an approach for certain types of decisions seems clearly called for. Moving forward in this direction will require acknowledgement that uncertainty and risk *do* exist, whether management activities occur or not.

The idea of "diversified approaches" (comparison of multiple approaches to accomplish the same objective) is described in chapter 10 of this volume as a tool for dealing with uncertainty in land management. Use of diversified approaches makes sense where there is significant uncertainty or risk, to avoid "putting all the eggs in one basket," and is helpful when there are questions about which approach among a group of alternatives will best meet objectives. The use of diverse approaches as a tool for developing new techniques for managing older forests in fire-prone areas may prove a good way to accelerate the development of needed improvements discussed elsewhere in this report.

Monitoring

The utility of a regional monitoring program has been verified, and a program has been established for selected Plan components. In addition to resource questions that it was designed to answer, the regional monitoring program significantly added new knowledge about how to design and implement a multiagency, scientifically rigorous monitoring program. In large part, the successes of the monitoring program arose from the strong commitment of resources by the agencies, and the establishment of a permanent full-time team to accomplish the work. An examination of how broad-scale interagency monitoring is accomplished

Box 14—Monitoring Findings

The regional monitoring program is in many respects functioning as expected, producing information about status and trends, and also producing significant information that will be useful for making improvements.

- Changing issues, new threats, and new information suggests that the monitoring questions should be reevaluated.
- In some cases, more quantitative targets should be established against which to evaluate the information obtained by monitoring. Examples include trends in populations of species of concern and watershed condition scores.
- Habitat models can be helpful in developing hypotheses, understanding relationships, and stratifying sample designs, but do not provide a surrogate for population monitoring.
- The Plan expectations for overall biodiversity monitoring have not been implemented, although much inventory information on rare and little-known older forest species was collected through the survey and manage effort and continues under the interagency special status species program.
- Incorporating fish population monitoring information from other agencies would significantly complement the aquatic/riparian monitoring that is occurring under the regional monitoring program.

Source: Chapter 10, this volume.

within agency financial structures, including an assessment of institutional barriers, could yield important information to help ensure an effective monitoring program in the future.


Ted Sedell

Stream monitoring crew taking measurements


Steve Lanigan

Fisheries biologists monitoring stream insects.


Steve Lanigan

Stream monitoring crew measuring stream width and depth.

There are significant improvements that could be made. New information suggests a revisit of the monitoring questions is needed, including a review of their applicability to Plan goals, and establishing more specific or different targets or benchmarks for monitored items. The information could significantly help future interpretations of status and trend information and ensure its relevance. A review would also provide information that could set new directions for continued Plan monitoring.

Scale and data resolution are key considerations in developing monitoring questions. Regional-scale monitoring is appropriate where (1) issues operate at that scale, (2) economies of scale can be captured, or (3) consistency of approach is essential. But regional-scale monitoring often lacks the resolution needed to answer finer scale questions. Ideally, fine-scale monitoring should contribute to addressing larger scale questions (for example, to help reduce overall costs), but often this requires a rigorous design to accommodate making inferences to larger areas, and there are few examples where this has been done successfully.

Besides asking the right questions and accumulating information at the right scale and resolution, expectations of a monitoring program need to match the resources available. The identification of information needs and the actual monitoring questions themselves need to continue to take into account the capacity of funding sources over the long term. Integrating monitoring information from multiple data sources has potential to reduce costs. Development and maintenance of common database systems and greater integration between modeling and monitoring (for example, to stratify sample design) also help make monitoring programs more efficient.

Under the Plan, interagency monitoring of older forests, northern spotted owls, and marbled murrelets, as well as surveys for old-forest-associated species conducted under the Survey and Manage program (and subsequently the special-status species program), have significantly increased knowledge of species about which little was known. Agencies invested a huge amount of effort and funding to achieve this outcome. The allocation of resources among specific monitoring priorities, and among activities and programs necessary to achieve the full range of intended Plan outcomes, warrants examination.

In spite of the significant investments for monitoring and surveys, it remains hard to say with certainty what the future trends of species persistence (a primary goal of the Plan) are likely to be, for all species believed to be associated with older forests. Although biodiversity monitoring was mandated by the Plan, it proved difficult to design an effective and affordable comprehensive approach for the large numbers of species involved. In the 10 years since the Plan was initiated, there have been many new developments in the field of biodiversity characterization and monitoring. In addition, the agencies already collect a large amount of information in existing regional inventories that could provide information on biodiversity without the expense of a special effort or creation of a formal “module.” Consideration of a new look at this subject in relation to biodiversity goals would likely be productive, especially if it is focused on answering questions at larger scales, integrates the coarse- and fine-filter dimensions of biodiversity conservation, and addresses both habitat and population questions. In the absence of the resources to undertake a huge effort that addresses all of the biodiversity questions, greater reliance on modeling may be a productive avenue for gaining information and forming hypotheses about how to provide protection for some species. In addition, some type of population and habitat monitoring and focused research would be valuable to assess species/habitat relationships, cause-and-effect relationships between management activities and species viability, and effectiveness of management direction to provide for species conservation. In the special-status species program, the agencies are currently emphasizing working with field offices on the identification of local and regional conservation needs, and on directing money and effort toward meeting those needs.

In addition to monitoring the effectiveness of the various components of the Plan, implementation monitoring was established to track overall compliance with the


Dave Baker

California Coast Provincial Advisory Committee evaluating project compliance with plan standards and guidelines.

Plan's standards and guidelines (Baker and others 2005). The effort used a statistically based design to sample land management projects (mainly timber sales, but also restoration projects and other silvicultural treatments), and relied heavily on participation by advisory groups to accomplish the work and achieve an independent assessment. In general, the results showed high compliance (less than 7 percent of the projects surveyed were less than 90 percent compliant), with recurring (but few) problems in the areas of snag retention, management of coarse woody debris, and riparian reserve management guidelines.[13] The high overall compliance rate suggests an opportunity to adjust the implementation monitoring program. Potential responses to the monitoring data include lengthening the monitoring interval or focusing on specific areas of concern. This adaptive management step would ensure that implementation monitoring questions are addressed cost effectively and could result in the availability of funds to meet other higher monitoring priorities. The potential for this type of monitoring to provide a foundation for future adjustments to the Plan is great. The program's move into more watershed-scale implementation monitoring in recent years could provide an opportunity for further assessment of progress toward meeting Plan goals, especially by providing additional context for interpretation of results from the other monitoring modules.

[13] Many of the observed departures from Plan standards and guidelines were due to overriding concerns, such as safety. For example, in some cases, snag densities fell below desired levels because of requirements to reduce hazardous trees in campgrounds or along roads.

Integration Among Scales

Implementation of the Plan started with a broad regional strategy, but is being carried out through assessments, plans, and activities at a whole host of different scales. For the Plan to succeed on the ground, there must be resonance and feedback across the various scales with regard to goals, strategies, plans, and monitoring. In the absence of such integration, it is difficult for local managers to develop program workplans and prioritize projects to accomplish the broader goals, because there is so little ability to tell how their individual project or set of activities does or does not contribute to the overall regional picture. In addition, it becomes very problematic to "roll up" individual actions and assess their collective effects on meeting goals.

One major task is that of identifying which scales are most appropriate to address particular resource issues or monitoring needs. Many issues are most appropriately addressed at some scale between the region and the project area, for example, prioritization of restoration efforts in watersheds. Another essential task is that of crafting a spatially explicit representation of target conditions (a "map" of the future forest patterns and conditions) at intermediate (i.e., watershed) scales against which to compare the projected cumulative effects of various combinations of fine-scale activities.

Management of older forests under the Plan is a good illustration of the need for integration across scales. The LSR network was designed at a *regional* scale to accomplish particular objectives, which drove the location, size, and connectivity among LSRs. The FEMAT team envisioned that there would be a finer scale look at individual or groups of LSRs, to ensure that management objectives and treatments are consistent with the *subregional* variation in ecological capability. At the *stand* scale, there are younger stands within LSRs for which treatments tailored to local conditions are needed to accomplish LSR structural and compositional objectives. Some way of connecting these different themes among scales is necessary to ensure the individual efforts are all actually achieving the desired goal.

Solving the dilemma of multiscale integration will likely involve:

- Determining the appropriate scales to address particular issues, to describe target landscape conditions, and Plan activities and outcomes.
- Developing means for feedback among and between scales by linking goals, plans, strategies, assessments, and monitoring across scales.
- Establishing priorities that address the greatest need in relation to available resources.
- Considering interrelations between actions on federal and nonfederal lands.

Box 15—Opportunities to Improve Collaboration

Renewed commitment to collaboration in the adaptive management areas.

- Learning from the existing models of successful agency-citizen collaboration in joint forest stewardship.
- Adequate planning for the time and financial resources collaboration consumes and planning accordingly.
- Facilitation of local-level decisionmaking so that there is a reason for communities to become engaged.

Source: Charnley and others 2006.

Organization and Function of Agency Groups and Stakeholders

Collaboration—

The complexity of overlapping goals, authorities, and interests in the Plan area has created a need for the various entities to coordinate their Plan implementation activities, requiring a highly collaborative model of management and decisionmaking. Even though the successes have not always been easy, inexpensive, or quick in coming, in the 10 years of Plan implementation, significant progress toward interagency collaboration has been made, including new organizational structures, improved relationships, shared expectations for success, and cooperative approaches to funding and staffing.

Plan implementation has also produced several good examples of improved involvement of nonagency stakeholders, including positive changes in the relationships between federal agencies and Native American tribes. Other improvements have occurred through the establishment of formal and informal committees and organizations, including many intergovernmental committees and work groups (for example, the RIEC, Intergovernmental Advisory Committee, Provincial Advisory Committees, watershed councils, etc.).

Some collaborative processes did not meet expectations (for example, those for some AMAs). And many field office employees and community members feel that the Plan moved the locus of decisionmaking to the regional level, reducing their ability to participate effectively.

In the face of declining budgets and staff, the roles of partnerships, volunteers, concessionaires, and joint forest stewardship activities have increased in importance as a way of helping federal agencies complete their work, including restoration activities, infrastructure maintenance, and interacting with the public. The capacity of local communities to engage in these activities is important to success and enhances the ability of agency field offices to participate.

Collaboration will likely remain a necessary feature of regional and local land management and decisionmaking,

David Burns

Karuk Tribe of California operating equipment to decommission the Steinacher road. Collaboration between the Karuk Tribe, Klamath and Six Rivers National Forests made this possible.

building on the foundation that has already been laid. The lessons learned thus far will be important as policies and relationships evolve to take into account the changing role of federal forests, and the ways in which management on federal and nonfederal lands affect or complement each other. The ability to "walk the talk" is essential to building trust, and creating realistic expectations about what actually can be accomplished is important as engagement of all forest landowners in conservation and development of strategies grows in the future.

Interagency program management and adaptation— Interagency management of the Survey and Manage and regional monitoring programs has yielded useful "lessons learned" to achieve greater efficiency, enhanced credibility, and reduced long-term costs. Some examples of interagency program features that enhanced success are:

- Active participation of researchers, resource staff, and managers in program design, data collection and analysis, and development and application of decision-support tools that integrate relevant information.
- Shared specific goals and objectives, expectations, and evaluation criteria.
- A permanent staff with necessary expertise (for example, in taxa biology/ecology, biometrics, etc.), effective organizational communication links, and clear connection to program goals.
- A monitoring and research framework to strategically focus resources on key information needs, and a plan for appropriate measures to fill those gaps.
- An effective information management infrastructure for data storage and analysis easily accessed and used by diverse users that will meet both short- and long-term information needs.
- Data collection efforts that achieve consistency and economies of scale, by being designed to address multiple species or resource issues and that allow for extrapolation of results to larger landscapes (that is, are probabilistic in design).
- A structured adaptive management process of accumulating new information and then rigorously evaluating that information through use of decision-support models and other means to identify potential adjustments.

The partnership between science and management— From the beginning, the Plan has entailed a close working relationship among the federal research organizations (USDA Forest Service Pacific Northwest and Pacific Southwest Research Stations; USDI Geological Survey, Western Research Region; and Environmental Protection Agency-Western Ecological Research Division) and the other agencies in the Plan area. At its best, this collaboration resulted in joint identification of research needs, pooling of resources to accomplish the necessary work, and shared interpretation of the implications of results. The AMAs provided a forum for exploring how this collaboration could play out on a very localized scale. The partnership has at times been challenging, given the differing roles, policy frameworks, jargon, reward systems, and organizational cultures between the two kinds of agencies.

In the latter half of the Plan's first decade, resources targeted at Plan research needs declined significantly. At the same time, new avenues for scientists to support Plan implementation have emerged, such as this volume. Clearly, the need for strong science underpinnings for the Plan continues. With the development of new issues and new tools for addressing them, a fresh look at science needs, along with the role science and scientists can play in the Plan, is timely.

Information Management

A separate report (Palmer and others 2005) on the management of the wealth of information accumulated as part of the regional monitoring effort was prepared by the Plan agencies. The report outlines the challenges and lessons learned, and also discusses the effect that information management problems had on the ability of the regional monitoring team to produce their reports. Some of this information is summarized in box 16.

Accessible, relevant, accurate data is the foundation of any effort to fill gaps in knowledge. The information management issues identified by the monitoring team may seem rather unexciting when compared to old-growth management issues in fire-prone ecosystems, or the causes of northern spotted owl population trends. But virtually all of what has been learned about the effects of policies and practices on lands and resources is shaped by the quality and nature of the information. Support of the information management function within the regional monitoring program, and integrating it into the larger data management processes of the individual agencies, will be essential if the agencies are to continue to benefit from and use the large amount of data that is being gathered. A key step in accomplishing this will be to prioritize information-gathering and management efforts in light of agency resources and funding.

Box 16–Problems Encountered in Regional Monitoring Information Management

- Some critical data do not exist, could not be found, or were not in a usable format.
- Some databases are not easily accessible outside agency firewalls.
- There are significant inconsistencies in data standards and formats within and among agencies, especially with stream and road data.
- Much information exists but has not been compiled across the analysis area.
- Data are seldom archived, updated, or maintained.
- There are significant gaps in documentation of data.
- Topics where improvements are most needed:
  - Ground-disturbing activities (timber harvest, road building)
  - Restoration activities
  - Riparian reserve boundaries
  - Streams (hydrography)
  - Land allocations and ownership
  - Roads
  - Vegetation
  - Fish passage/barriers
  - Potential natural vegetation
  - Contracting data for projects

Source: Palmer and others 2005.

Conclusions

At this 10-year anniversary of the Plan, the monitoring and new science information suggests both that the overall framework of the Plan is working, and that certain improvements are needed in order to meet the goals. The following suggestions summarize the major implications of the series of 10-year monitoring and research reports:

Plan Scope:

- Reconsider the management goals for federal lands, giving greater attention to the overall context of land ownerships and the contributions of other lands and policies to meeting the goals envisioned by the Plan.
- Incorporate new information on emerging threats (climate change, invasive species) into management direction, and take steps to address the uncertainties.

Plan Components:

- Consider revisions to late-successional and old-growth forest management in areas with a natural history of frequent, low-intensity fires.
- Using new science information, create analysis guidelines for adjustment of riparian reserve boundaries and management direction.
- Revisit the key watershed concept and network.

Plan Implementation:

- Adapt the regional monitoring program by
  - Revisiting the monitoring questions (including the desired scale and resolution of data) to ensure the next decade's issues are addressed.
  - Establishing more specific goals and benchmarks.
  - Seeking a better balance among costs, benefits, and expectations.
- Find ways to increase support for taking measured risks in efforts to be successful at adaptive management.
- Continue to improve interagency and stakeholder collaboration; streamline processes and build trust.
- Develop, communicate, and use (in policies and decisions) a clearer understanding of new knowledge about the contribution of federal lands and resources to the regional economy and to communities near federal lands.
- Continue the productive partnership between research, consulting, and land management agencies to identify and fill significant knowledge gaps with needed research and assessments, to provide the basis for future Plan adjustments.
- Make improvements in the management of information, especially accessibility and consistency. Focus on critical data needs.
- Continue to seek ways to help achieve the balance of environmental and economic outcomes envisioned in the Plan.

The extent to which the Plan agencies are able to move forward on these findings will be largely dependent on the priorities set by the RIEC within the considerable constraints on financial and personnel resources that exist, as well as the sideboards set by the laws, policies, and regulations under which the public forest lands and resources are managed.

As far as we know, the series of reports associated with the 10-year review of the Plan constitutes a unique example of adaptive management, in terms of the breadth of topics covered, the sheer size and diversity of the area covered by the Plan, the large number of agency partners and other collaborators, and, perhaps most importantly, in the transparency of the process of sharing new information and developing future policies and actions. The reports for the next decade will no doubt be vastly streamlined and improved, but clearly this decade's effort has established that adaptive management can work at the Plan scale, and provides a good framework for establishing a basis upon which sustainable policies and decisions can be made.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet	.3048	Meters
Cubic feet	.0283	Cubic meters
Miles	1.609	Kilometers
Acres	.405	Hectares
Board feet, log scale	.0045	Cubic meters, log
Board feet, full sawn lumber scale	.0024	Cubic meters, lumber

Glossary

This glossary has evolved from the Forest Ecosystem Management Assessment Team report (FEMAT 1993).

adaptive management—The process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans.

adaptive management areas—Landscape units designated for development and testing of technical and social approaches to achieving desired ecological, economic, and other social objectives.

age class—A management classification using the age of a stand of trees.

alluvial—Originated through the transport by and deposition from running water.

aquatic ecosystem—Any body of water, such as a stream, lake, or estuary, and all organisms and nonliving components within it, functioning as a natural system.

aquatic habitat—Habitat that occurs in free water.

associated species—A species found to be numerically more abundant in a particular forest successional stage or type compared to other areas.

baseline—The starting point for analysis of environmental consequences. This may be the conditions at a point in time (for example, when inventory data are collected) or may be the average of a set of data collected over a specified period).

biological diversity—Various life forms and processes, including a complexity of species, communities, gene pools, and ecological functions.

biomass—The total quantity (at any given time) of living organisms of one or more species per unit of space (species biomass), or of all the species in a biotic community (community biomass).

blowdown—Trees felled by high winds.

board foot—Lumber or timber measurement term. The amount of wood contained in an unfinished board 1 inch thick, 12 inches long, and 12 inches wide.

breast height—A standard height from ground level for recording diameter, girth, or basal area of a tree, generally 4.5 feet.

Bureau of Land Management—A division within the U.S. Department of the Interior.

canopy—A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand.

clearcut—A harvest in which all or almost all of the trees are removed in one cutting.

coarse woody debris—Portion of a tree that has fallen or been cut and left in the woods. Usually refers to pieces at least 20 inches in diameter.

colonization—The establishment of a species in an area not currently occupied by that species. Colonization often involves dispersal across an area of unsuitable habitat.

community—(1) Pertaining to human associations based on social interactions, shared interests, norms, or values, or geography, (2) Pertaining to plant or animal species living in close association and interacting as a unit.

conifer—A tree belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones (hence, coniferous) and have needle-shaped or scalelike leaves.

connectivity—A measure of the extent to which conditions among late-successional and old-growth forest areas (LSOG) provide habitat for breeding, feeding, dispersal, and movement of LSOG-associated wildlife and fish species (see LSOG habitat).

conservation—The process or means of achieving recovery of viable populations.

conservation strategy—A management plan for a species, group of species, or ecosystem that prescribes standards and guidelines that, if implemented, provide a high likelihood that the species, groups of species, or ecosystem, with its full complement of species and processes, will continue to exist well distributed throughout a planning area; that is, a viable population.

corridor—A defined tract of land, usually linear, through which a species must travel to reach habitat suitable for reproduction and other life-sustaining needs.

cover—Vegetation used by wildlife for protection from predators, or to mitigate weather conditions, or to reproduce. May also refer to the protection of the soil and the shading provided to herbs and forbs by vegetation.

cumulative effects—Those effects on the environment that result from the incremental effect of the action when added to the past, present, and reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period.

debris flow (debris torrent)—A rapid-moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand.

demography—The quantitative analysis of population structure and trends; population dynamics.

desired future condition—An explicit description of the physical and biological characteristics of aquatic and riparian environments believed necessary to meet fish, aquatic ecosystem, and riparian ecosystem objectives.

diameter at breast height—The diameter of a tree 4.5 feet above the ground on the uphill side of the tree.

dispersal—The movement, usually one way and on any time scale, of plants or animals from their point of origin to another location where they subsequently produce offspring.

distribution (of a species)—The spatial arrangement of a species within its range.

disturbance—A force that causes significant change in structure and composition through natural events such as fire, flood, wind, or earthquake, mortality caused by insect or disease outbreaks, or by human activities, for example, the harvest of forest products.

diversity—The variety, distribution, and abundance of different communities or species within an area (see biological diversity).

down log—Portion of a tree that has fallen or been cut and left in the woods. Particularly important as habitat for some late-successional and old-growth-associated species.

draft environmental impact statement (DEIS)—The draft statement of environmental effects that is required for major federal action under Section 102 of the National Environment Policy Act, and released to the public and other agencies for comment and review.

drainage—An area (basin) mostly bounded by ridges or other similar topographic features, encompassing part, most, or all of a watershed and enclosing some 5,000 acres.

ecosystem—A unit comprising interacting organisms considered together with their environment (for example, marsh, watershed, and lake ecosystems).

ecosystem diversity—Various species and ecological processes that occur in different physical settings.

ecosystem management—A strategy or plan to manage ecosystems to provide for all associated organisms, as opposed to a strategy or plan for managing individual species.

edge—Where plant communities meet or where successional stages or vegetative conditions of plant communities come together.

endangered species—Any species of plant or animal defined through the Endangered Species Act as being in danger of extinction throughout all or a significant portion of its range, and published in the Federal Register.

environmental assessment—A systematic analysis of site-specific activities used to determine whether such activities have a significant effect on the quality of the human environment and whether a formal environmental impact statement is required; also to aid an agency's compliance with the National Environmental Policy Act when no environmental impact statement is necessary.

environmental impact—The positive or negative effect of any action on a given area or resource.

environmental impact statement (EIS)—A formal document to be filed with the Environmental Protection Agency that considers significant environmental impacts expected from implementation of a major federal action.

Environmental Protection Agency—An independent agency of the U.S. Government.

ephemeral streams—Streams that contain running water only sporadically, such as during and following storm events.

even-age silviculture—Manipulation of a forest stand to achieve a condition in which trees have less than a 20-year age difference. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for harvesting. Clearcut, shelterwood, or seed-tree cutting methods result in even-aged stands.

experimental forests—Forest tracts, generally on national forests, designated as areas where research and experiments involving forestry, wildlife, and related disciplines can be conducted.

extirpation—The elimination of a species from a particular area.

filter—Coarse filter management refers to management of overall ecosystems and habitats.

Fine filter management refers to management of specific habitats or sites for selected individual species.

final environmental impact statement (FEIS)—The final report of environmental effects of proposed action on an area of land. This is required for major federal actions under Section 102 of the National Environmental Policy Act. It is a revision of the draft environmental impact statement to include public and agency responses to the draft.

Forest Ecosystem Management Assessment Team (FEMAT)—As assigned by President Clinton, the team of scientists, researchers, and technicians from seven federal agencies who created the FEMAT report (1993).

function—The flow of mineral nutrients, water, energy, or species.

geomorphic—Pertaining to the form or shape of those processes that affect the surface of the Earth.

geographic information system—A computer system capable of storing and manipulating spatial (that is, mapped) data.

green-tree retention—A stand management practice in which live trees as well as snags and large down wood are left as biological legacies within harvest units to provide habitat components over the next management cycle.

guideline—A policy statement that is not a mandatory requirement (as opposed to a standard, which is mandatory).

habitat—The place where a plant or animal naturally or normally lives and grows.

habitat diversity—The number of different types of habitat within a given area.

habitat fragmentation—The breaking up of habitat into discrete islands through modification or conversion of habitat by management activities.

impact—A spatial or temporal change in the environment caused by human activity.

Interagency Scientific Committee (ISC)—A committee of scientists that was established by the Forest Service, Bureau of Land Management, Fish and Wildlife Service, and National Park Service to develop a conservation strategy for northern spotted owls.

interdisciplinary team—A group of individuals with varying areas of specialty assembled to solve a problem or perform a task. The team is assembled out of recognition that no one scientific discipline is sufficiently broad enough to adequately analyze the problem and propose action.

intermittent stream—Any nonpermanent flowing drainage feature having a definable channel and evidence of scour or deposition. This includes what are sometimes referred to as ephemeral streams if they meet these two criteria.

issue—A matter of controversy or dispute over resource management activities that is well defined or topically discrete. Addressed in the design of planning alternatives.

key watershed—As defined by National Forest System and Bureau of Land Management district fish biologists, a watershed containing (1) habitat for potentially threatened species or stocks of anadromous salmonids or other potentially threatened fish, or (2) greater than 6 square miles with high-quality water and fish habitat.

land allocation—The specification in forest plans of where activities, including timber harvest, can occur on a National Forest System or Bureau of Land Management district.

landscape—A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout.

large woody debris—Pieces of wood larger than 10 feet long and 6 inches in diameter, in a steam channel.

late-successional old-growth habitat—A forest in its mature or old-growth stages.

late-successional reserve—A forest in its mature or old-growth stages that has been reserved under a management option (see "old-growth forest" and "succession").

low-level green-tree retention—A regeneration harvest designed to retain only enough green trees and other structural components (snag, coarse woody debris, etc.) to result in the development of stands that meet old-growth definitions within 100 to 120 years after harvest entry, considering overstory mortality.

management activity—An activity undertaken for the purpose of harvesting, traversing, transporting, protecting, changing, replenishing, or otherwise using resources.

marbled murrelet—A small robin-sized seabird (*Brachyramphus marmoratus*) that nests in old-growth forests within 50 miles of marine environments. Listed as a threatened species in California, Oregon, and Washington by the U.S. Fish and Wildlife Service.

marbled murrelet habitat—Primarily late-successional old-growth forest with trees that are large enough and old enough to develop broad crowns and large limbs that provide substrates for nests. Also includes some younger stands in which tree limbs are deformed by dwarf mistletoe, creating broad platforms.

matrix—Federal lands not in reserves, withdrawn areas, or managed late-successional areas.

mature stand—A mappable stand of trees for which the annual net rate of growth has peaked. Stands are generally greater than 80 to 100 years old and less than 180 to 200 years old. Stand age, diameter of dominant trees, and stand structure at maturity differ by forest cover types and local site conditions. Mature stands generally contain trees with a smaller average diameter, less age-class variation, and less structural complexity than old-growth stands of the same forest type. Mature stages of some forest types are suitable habitat for spotted owls. However, mature forests are not always spotted owl habitat, and spotted owl habitat is not always mature forest.

model—An idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it; a mathematical representation of the relations under study. The term model is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations.

monitoring—The process of collecting information to evaluate if objective and anticipated or assumed results of a management plan are being realized or if implementation is proceeding as planned.

monitoring program—The administrative program used for monitoring.

multiple use—Land management strategy often applied on public lands that emphasizes using various resource values in the combination that will best meet the present and future societal needs. It includes the use of some land for only some resources and, overall, provides a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific, and historical values.

multistoried—Forest stands that contain trees of various heights and diameter classes and therefore support foliage at various heights in the vertical profile of the stand.

National Environmental Policy Act—An act passed in 1969 that encourages productive and enjoyable harmony between humankind and the environment, promotes efforts that will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of humanity, enriches the understanding of the ecological systems and natural resources important to the Nation, and establishes a Council on Environmental Quality (The Principal Laws Relating to Forest Service Activities, Agric. Handb. 453. USDA Forest Service 1983).

National Forest Management Act—A law passed in 1976 as an amendment to the Forest and Rangeland Renewable Resources Planning Act, requiring the preparation of forest plans and the preparation of regulations to guide that development.

National Marine Fisheries Service—A division within the U.S. Department of Commerce.

National Park Service—A division within the U.S. Department of the Interior.

northern spotted owl—One (*Strix occidentalis caurina*) of three subspecies of the spotted owl that ranges from southern British Columbia, Canada, through western Washington and Oregon, and into northwestern California. Listed as a threatened species by the U.S. Fish and Wildlife Service.

old growth—This stage constitutes the potential plant community capable of existing on a site given the frequency of natural disturbance events. For forest communities, this stage exists from about age 200 until stand replacement occurs and secondary succession begins again. Depending on fire frequency and intensity, old-growth forests may have different structures, species composition, and age distributions. In forests with longer periods between natural disturbance, the forest structure will be more even-aged at late mature or early old-growth stages.

old-growth forest—A forest stand usually at least 180 to 220 years old with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; high incidence of large trees, some with broken tops and other indications of old and decaying wood (decadence); many large snags; and heavy accumulations of wood, including large logs on the ground.

old-growth stand—A mappable area of old-growth forest.

overstory—Trees that provide the uppermost layer of foliage in a forest with more than one roughly horizontal layer of foliage.

owl region—The geographic area within the range of the northern spotted owl.

peak flow—The highest amount of stream or river flow occurring in a year or from a single storm event.

perennial stream—A stream that typically has running water on a year-round basis.

physiographic province—A geographic area having a similar set of biophysical characteristics and processes because of the effects of climate and geology that result in patterns of soils and broad-scale plant communities. Habitat patterns, wildlife distributions, and historical land use patterns may differ significantly from those of adjacent provinces.

planning area—All the lands within a federal agency's management boundary addressed in land management plans.

plant association—A plant community type based on land management potential, successional patterns, and species composition.

plant community—An association of plants of various species found growing together in different areas with similar site characteristics.

population—A collection of individual organisms of the same species that potentially interbreed and share a common gene pool. Population density refers to the number of individuals of a species per unit area, population persistence to the capacity of the population to maintain sufficient density to persist, well distributed, over time (see "viable population").

population dynamics—The aggregate of changes that occur during the life of a population. Included are all phases of recruitment and growth, senility, mortality, seasonal fluctuation in biomass, and persistence of each year class and its relative dominance, and the effects that any or all of these factors exert on the population.

population viability—Probability that a population will persist for a specified period across its range despite normal fluctuations in population and environmental conditions.

predator—Any animal that preys on others by hunting, killing, and generally feeding on a succession of hosts, that is, the prey.

prescribed fire—A fire burning under specified conditions that will accomplish certain planned objectives. The fire may result from planned or unplanned ignitions.

process—Change in state of an entity.

range (of a species)—The area or region over which an organism occurs.

record of decision (ROD)—A document separate from but associated with an environmental impact statement that states the management decision, identifies all alternatives including both the environmentally preferable and preferred alternatives, states whether all practicable means to avoid environmental harm from the preferred alternative have been adopted and, if not, why not.

recovery—Action that is necessary to reduce or resolve the threats that caused a species to be listed as threatened or endangered.

reforestation—The natural or artificial restocking of an area with forest trees; most commonly used in reference to artificial stocking.

refugia—Locations and habitats that support populations of organisms that are limited to small fragments of their previous geographic range (that is, endemic populations).

regeneration—The actual seedlings and saplings existing in a stand; or the act of establishing young trees naturally or artificially.

region—A Forest Service administrative unit. For example, the Pacific Northwest Region (Region 6) includes national forests in Oregon and Washington, and the Pacific Southwest Region (Region 5) includes national forests in California.

regional guide—The guide developed to meet the requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974, as amended (National Forest Management Act). Regional guides provide standards and guidelines for addressing major issues and management concerns that need to be considered at the regional level to facilitate national forest planning.

regulation models—For a forest, different ways of controlling stocking, harvests, growth, and yields to meet management objectives.

riparian area—A geographic area containing an aquatic ecosystem and adjacent upland areas that directly affect it. This includes flood plain, woodlands, and all areas within a horizontal distance of about 100 feet from the normal line of high water of a steam channel or from the shoreline of a standing body of water.

riparian reserves—Designated riparian areas found outside the late-successional reserves.

riparian zone—Those terrestrial areas where the vegetation complex and microclimate conditions are products of the combined presence and influence of perennial and intermittent water, associated high water tables, and soils that exhibit some wetness characteristics. Normally used to refer to the zone within which plants grow rooted in the water table of these rivers, streams, lakes, ponds, reservoirs, springs, marshes, seeps, bogs, and wet meadows.

risk analysis—A qualitative assessment of the probability of persistence of wildlife species and ecological systems under various alternatives and management options; generally also accounts for scientific uncertainties.

rotation—The planned number of years between regeneration of a forest stand and its final harvest (regeneration cut or harvest). The age of a forest at final harvest is referred to as rotation age. In the Douglas-fir region, an extended rotation is 120 to 180 years, a long rotation 180 years.

scale—The level of spatial or temporal resolution perceived or considered.

sensitive species—Those species that (1) have appeared in the Federal Register as proposed for classification and are under consideration for official listing as endangered or threatened species or (2) are on an official state list or (3) are recognized by the USDA Forest Service or other management agency as needing special management to prevent their being placed on federal or state lists.

seral stage—See glossary table 1 for three alternative definitions.

shade-tolerant species—Plant species that have evolved to grow well in shade.

silvicultural practices (or treatments or system)—The set of field techniques and general methods used to modify and manage a forest stand over time to meet desired conditions and objectives.

silvicultural prescription—A professional plan for controlling the establishment, composition, constitution, and growth of forests.

silviculture—The science and practice of controlling the establishment, composition, and growth of the vegetation of forest stands. It includes the control or production of stand structures such as snags and down logs in addition to live vegetation.

simulation—The use of a computer or mathematical model to predict effects from a management option given different sets of assumptions about population vital rates.

site productivity—The ability of a geographic area to produce biomass, as determined by conditions (for example, soil type and depth, rainfall, temperature) in that area.

snag—Any standing dead, partially dead, or defective (cull) tree at least 10 inches in diameter at breast height and at least 6 feet tall. A hard snag is composed primarily of sound wood, generally merchantable. A soft snag is composed primarily of wood in advanced stages of decay and deterioration, generally not merchantable.

soil compaction—An increase in bulk density (weight per unit volume) and a decrease in soil porosity resulting from applied loads, vibration, or pressure.

soil productivity—Capacity or suitability of a soil for establishment and growth of a specified crop or plant species, primarily through nutrient availability.

species—(1) A group of individuals that have their major characteristics in common and are potentially interfertile. (2) The Endangered Species Act defines species as including any species or subspecies of plant or animal. Distinct populations of vertebrates also are considered to be species under the act.

species diversity—The number, different kinds, and relative abundance of species.

stand (tree stand)—An aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement, and condition so that it is distinguishable from the forest in adjoining areas.

stand condition—A description of the physical properties of a stand such as crown closure or diameters.

stand-replacing event—A disturbance that is severe enough over a large enough area (for example, 10 acres) to virtually eliminate an existing stand of trees and initiate a new stand.

standards and guidelines—The primary instructions for land managers. Standards address mandatory actions, whereas guidelines are recommended actions necessary to a land management decision.

stochastic—Random, uncertain; involving a random variable.

stocked-stocking—The degree to which an area of land is occupied by trees as measured by basal area or number of trees.

stream order—A hydrologic system of stream classification. Each small unbranched tributary is a first-order stream. Two first-order streams join to make a second-order stream. A third-order stream has only first-and second-order tributaries, and so forth.

stream reach—An individual first-order stream or a segment of another stream that has beginning and ending points at a stream confluence. Reach end points are normally designated where a tributary confluence changes the channel character or order. Although reaches identified by the Bureau of Land Management are variable in length, they normally have a range of 0.5 to 1.5 miles in length unless channel character, confluence distribution, or management considerations require variance.

structure—The various horizontal and vertical physical elements of the forest.

stumpage—The volume or value of standing timber.

succession—A series of dynamic changes by which one group of organisms succeeds another through stages leading to potential natural community or climax. An example is the development of series of plant communities (called seral stages) following a major disturbance.

successional stage—A stage or recognizable condition of a plant community that occurs during its development from bare ground to climax. For example, coniferous forests in the Blue Mountains progress through six recognized stages: grass-forb, shrub-seedling, pole-sapling, young, mature, and old growth.

suppression—The action of extinguishing or confining a fire.

surface erosion—A group of processes whereby soil materials are removed by running water, waves and currents, moving ice, or wind.

sustainable harvest—A harvest volume that can be maintained through time without decline.

take—Under the Endangered Species Act, take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect an animal, or to attempt to engage in any such conduct.

threatened species—Those plant or animal species likely to become endangered species throughout all or a significant portion of their range within the foreseeable future. A plant or animal identified and defined in accordance with the 1973 Endangered Species Act and published in the Federal Register.

timber production—The purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use other than for fuelwood.

unique ecosystems—Ecosystems embracing special habitat features such as beaches and dunes, talus slopes, meadows, and wetlands.

U.S. Department of Agriculture (USDA)—Federal land management agency whose main mission is multiple use of lands under its jurisdiction.

U.S. Department of the Interior (USDI)—Federal land management agency whose main mission is multiple use of lands under its jurisdiction.

viability—The ability of a wildlife or plant population to maintain sufficient size so that it persists over time in spite of normal fluctuations in numbers; usually expressed as a probability of maintaining a specific population for a specified period.

viable population—A wildlife or plant population that contains an adequate number of reproductive individuals appropriately distributed on the planning area to ensure the long-term existence of the species.

water quality—The chemical, physical, and biological characteristics of water.

watershed—The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake.

watershed analysis—A systematic procedure for characterizing watershed and ecological processes to meet specific management and social objectives. Watershed analysis is a stratum of ecosystem management planning applied to watersheds of about 20 to 200 square miles.

watershed restoration—Improving current conditions of watersheds to restore degraded fish habitat and provide long-term protection to aquatic and riparian resources.

well distributed—A geographic distribution of habitats that maintains a population throughout a planning area and allows for interaction of individuals through periodic interbreeding and colonization of unoccupied habitats.

wetlands—Areas that are inundated by surface water or ground water with a frequency sufficient to support, and that under normal circumstances do or would support, a prevalence of vegetative or aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction (Executive Order 11990). Wetlands generally include, but are not limited to, swamps, marshes, bogs, and similar areas.

wilderness—Areas designated by congressional action under the 1964 Wilderness Act. Wilderness is defined as undeveloped federal land retaining its primeval character and influence without permanent improvements or human habitation. Wilderness areas are protected and managed to preserve their natural conditions, which generally appear to have been affected primarily by the forces of nature, with the imprint of human activity substantially unnoticeable; have outstanding opportunities for solitude or for a primitive and confined type of recreation; include at least 5,000 acres or are of sufficient size to make practical their preservation, enjoyment, and use in an unimpaired condition; and may contain features of scientific, education, scenic, or historical value as well as ecologic and geologic interest.

wildfire—Any wildland fire that is not a prescribed fire.

windfall—Trees or parts of trees felled by high winds (see also "blowdown" and "windthrow").

windthrow—Synonymous with windfall, blowdown.

young stands—Forest stands not yet mature, generally less than 50 to 80 years old; typically 20 to 40 years old.

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Glossary Table 1—Major classification schemes used to describe forest developmental stages and associated characteristics[a]

Forest development stage	Ecosystem perspective: Ecological structure and process	Ecosystem perspective: Wildlife habitat	Ecosystem perspective: Timber production
First	Reorganization (Bormann and Likens 1979) Stand initiation (Oliver and Larson 1990) Establishment (Spies and Franklin 1991) Ecosystem initiation (Carey and Curtis 1996) Disturbance/legacy creation and cohort establishment (Franklin and others 2002)	Grass/forb-open, grass/forb-closed, shrub/seedling-open, shrub/seedling-closed, sapling/pole-open (O'Neil and others 2001)	Seedling (Haynes 2003) Early seral (FEMAT 1993)
Characteristics	• Pioneer tree cohort established with a range of regeneration densities • Biological legacies present depending on initial disturbance type, intensity and management • Rapid biomass accumulation • Above- and belowground resource availability high • Nutrient transfer from soil to biomass • Possible introduction and spread of exotic/invasive species	• Biodiversity high • Herb and shrub understory may be abundant or persistent • Open canopy conditions important for birds and mammals • Biological legacies retained provide habitat	• Stand age typically 0 to 15 years • Single-species tree cohort densely seeded or planted, typically with genetically altered stock • Competing vegetation controlled or removed • Precommercial • Includes first tree age class of seedlings (average age of 5 years)
Second	Aggradation (Bormann and Likens 1979) Stem (Oliver and Larson 1990) Thinning (Spies and Franklin 1991) Competitive exclusion (Carey and Curtis 1996) Canopy closure (Franklin and others 2002)	Sapling/pole-moderate, sapling/pole-closed (O'Neil and others 2001)	Poles and saplings (Haynes 2003) Mid-seral (FEMAT 1993)
Characteristics	• Taller vegetation becomes dominant • Leaf area and biomass accumulate • Canopies close on some sites—rate depends on regeneration density and site productivity • Few snags and coarse woody debris (CWD) in managed stands • Rapid understory environment changes • Resource availability decline	• Biodiversity declines • Depending on canopy structure, herb and shrub understory abundance declines • Amphibians associated with closed canopies • Minimize stage through precommercial and variable-density thinning	• Stand age typically 15 to 35 years • Conventional precommercial thinning to maintain evenly spaced trees and promote tree growth • Pole- and sapling-sized trees usually not merchantable • Commercial thinning can occur depending on market conditions

Glossary Table 1—Major classification schemes used to describe forest developmental stages and associated characteristics[a] (continued)

Forest development stage	Ecosystem perspective		
	Ecological structure and process	**Wildlife habitat**	**Timber production**
Third	Aggradation (Bormann and Likens 1979) Stem exclusion (Oliver and Larson 1990) Thinning (Spies and Franklin 1991) Competitive exclusion (Carey and Curtis 1996) Biomass accumulation/competitive exclusion (Franklin and others 2002)	Small tree-single story-moderate, small tree-single story-closed, medium tree-single story-moderate, medium tree-single story-closed, large tree-single story-moderate, large tree-single story-closed (O'Neil and others 2001)	Young (Haynes 2003) Late seral (FEMAT 1993)
Characteristics	• Woody biomass development • Tree crown differentiation and lower branch pruning • Low resource availability early, increases later • Density-dependent tree mortality with high stand density • Few snags and CWD • Competitive exclusion of many organisms	• Low biodiversity • Depending on canopy structure, herb and shrub abundance may be low • Amphibians associated with closed canopies • Minimize stage through precommercial and variable-density thinning	• Stand age typically 45 to 75 years • Pioneer tree cohort dominates site • Sawtimber and nonsawtimber-size trees • Conventionally thought of as the culmination of mean annual increment • For many private industrial landowners, may reflect typical rotation lengths and stand developments ends
Fourth	Transition (Bormann and Likens 1979) Understory reinitiation (Oliver and Larson 1990) Mature (Spies and Franklin 1991) Understory reinitiation, developed understory (Carey and Curtis 1996) Maturation (Franklin and others 2002)	Small tree-single story-open, medium tree-single story-open, large tree-single story-open (O'Neil and others 2001)	Mature seral (FEMAT 1993) Mature (Haynes 2003)
Characteristics	• Maximum height and crown spread of pioneer tree cohort • Minimal coarse woody debris • Heterogeneous resource availability • Shift to density-independent mortality • Sub-lethal tree damage produces greater individual tree conditions and niche diversification	• Extended rotations (>80 years) to provide habitat • Reestablishment of understory species, including shade-tolerant conifers • Increase in diversity of fauna, especially with multistored canopies • Increased habitat through commercial thinning and CWD management	• Stand age typically 85 to 135 years • Less common stage on private industrial lands • Composed mostly of sawtimber-size trees • Conventionally thought of as over culmination of mean annual increment

Glossary Table 1—Major classification schemes used to describe forest developmental stages and associated characteristics[a] (continued)

Forest development stage	Ecosystem perspective		
	Ecological structure and process	Wildlife habitat	Timber production
Fifth	Steady-state (Bormann and Likens 1979) Old-growth (Oliver and Larson 1990) Transition and shifting-gap (Spies and Franklin 1996) Botanically diverse, niche diversification fully functional (managed) and old growth (Carey and Curtis 1996) Vertical diversification, horizontal diversification and pioneer cohort loss (Franklin and others 2002)	Small tree-multistory-open, small tree-multistory-moderate, small tree-multistory-closed, medium tree-multistory-open, medium tree-multistory-moderate, medium tree-multistory-closed, large tree-multistory-open, large tree-multistory-moderate, large tree-multistory-closed, giant tree-multistory (O'Neil and others 2001)	Mature (FEMAT 1993) Old mature stage (Haynes 2003)
Characteristics	• Slow decline in aboveground biomass • Many substages for long-lived species • Development of late-successional and old-growth attributes (Spies and Franklin 1996) • Density-independent mortality increases, large, persistent gaps may form • Accelerated generation of CWD • Highly heterogeneous resource availability • Sublethal tree damage continues • Loss of dominants (800 to 1,300 yrs.)	• Extended rotations to provide habitat • Large trees, multiple stories, snags, CWD, and closed canopies create habitats for numerous species • Faunal diversity, especially birds and mammals is high	• Stand age typically more than 145 years • Uncommon stage on private industrial lands • Conventionally thought of as past the point where net annual growth has peaked

[a] Characteristics are illustrated from various ecosystem perspectives by using a Douglas-fir-dominated sere growing in the western hemlock zone (Franklin and Dyrness 1988). Characteristics will vary widely based on site location, disturbance history, management, and forest type. This table was developed by B. Kerns (see Monserud et al. 2003).

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Appendix

Common and Scientific Names of Species

Common name	Scientific name
Flora:	
Aspen	*Populus* spp.
Fir	*Abies* spp.
Hemlock	*Tsuga* spp.
California black oak	*Quercus kelloggii* Newberry
Douglas-fir	*Pseudotsuga menziesii* (Mirbel) Franco.
Grand fir	*Abies grandis (*Dougl. ex D. Don) Lindl.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.
Tanoak	*Lithocarpus* spp. Blume
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western redcedar	*Thuja plicata* Donn ex D. Don
Bear grass	*Xerophyllum* spp. Michx.
Salal	*Gaultheria shallon* Pursh
Trailing blackberry	*Rubus ursinus* Cham. & Schlecht.
Aquatic species:	
Fish—	
Pacific salmon	*Oncorhynchus* spp.
Bull trout	*Salvelinus confluentus*
Coastal cutthroat trout	*Oncorhynchus clarkii clarkii*
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Cutthroat trout	*Oncorhynchus clarkii*
Lost River sucker	*Deltistes luxatus*
Shortnose sucker	*Chasmistes brevirostris*
Steelhead	*Oncorhynchus mykis*
Oregon chub	*Oregonichthys crameri*
Amphibians and reptiles—	
del Norte salamander	*Plethodon elongatus*
Terrestrial species:	
Birds—	
Jay	*Cyanocitta* spp.
Raven	*Corvus* spp.
Crow	*Corvus* spp.
Barred owl	*Strix varia*
Marbled murrelet	*Brachyramphus marmoratus*
Northern spotted owl	*Strix occidentalis caurina*
Pileated woodpecker	*Dryocopus pileatus*
Mammals:	
Wood rat	*Neotoma* spp.
Red tree vole	*Arborimus longicaudus*
Disease:	
Sudden oak death	*Phytophthora ramorum*

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